Massachusetts Institute of Technology

Reports to the President

1986-87
Reports for this book were submitted for publication in final, camera-ready form by MIT departments, laboratories, and centers.
Corporation
1986-87

Honorary Chairman: Howard W. Johnson
Chairman: David S. Saxon
President: Paul E. Gray
Treasurer: Glenn P. Strehle
Secretary: Constantine B. Simonides

LIFE MEMBERS


MEMBERS


PRESIDENT OF THE ALUMNI ASSOCIATION

Joseph G. Gavin, Jr.

REPRESENTATIVES OF THE COMMONWEALTH

Governor: His Excellency, Michael S. Dukakis
Chief Justice of the Supreme Judicial Court: The Honorable Edward F. Hennessey
Commissioner of Education: Harold Raynolds, Jr.

LIFE MEMBERS EMERITI

Contents

PRESIDENT ........................................... 7
   In Special Recognition ............................. 15
   Statistics for the Year ........................... 18
   Personnel Changes ................................ 21

PROVOST ............................................. 37
   Libraries .......................................... 39
   Lincoln Laboratory ................................ 45
   Project Athena ...................................... 52

Associate Provost and Vice President for Research .................. 55
   Francis Bitter National Magnet Laboratory ........... 55
   Center for Cognitive Science ........................ 58
   Center for Materials Science and Engineering ........ 61
   Division of Comparative Medicine .................... 64
   Energy Laboratory .................................. 65
   Harvard-MIT Division of Health Sciences and Technology .... 68
   Mining and Mineral Resources Research Institute ....... 70
   Northeast Radio Observatory Corporation/Haystack Observatory ... 71
   Nuclear Reactor Laboratory ........................ 74
   Operations Research Center ........................ 79
   Plasma Fusion Center ................................ 82
   Research Laboratory of Electronics .................. 90
   Sea Grant College Program ........................... 95
   Technology and Development Program .................. 99
   Technology Licensing Office ........................ 102
   Whitaker College of Health Sciences, Technology, and Management ... 103
   Department of Brain and Cognitive Sciences ............ 106
   Clinical Research Center ............................ 108

Associate Provost for Educational Programs and Policy .............. 112
   Office of the Dean for Undergraduate Education ........ 112
   Committee on the Undergraduate Program ................ 113
   Office for Undergraduate Education (Concourse, Curriculum Support, UROP, Writing Requirement) ................ 115
   Office of the Dean of the Graduate School ............. 124
   Lowell Institute School ................................ 143
   Summer Session ...................................... 144
   Upward Bound Program ................................ 145
   ROTC Programs ....................................... 146
   MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering ........................................ 149

Office of the Dean for Student Affairs .......................... 150
   Facilities Use Committee ................................ 163

CHAIRMAN OF THE FACULTY .................................. 164

SCHOOL OF ARCHITECTURE AND PLANNING ......................... 169
   Department of Architecture ........................... 173
   Department of Urban Studies and Planning ............... 177
   Aga Khan Program for Islamic Architecture ................ 179
   Center for Advanced Visual Studies .................... 181
   Center for Real Estate Development ..................... 182
   Laboratory of Architecture and Planning ................. 183
   Media Laboratory ...................................... 186
### SCHOOL OF ENGINEERING

<table>
<thead>
<tr>
<th>Department</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Aeronautics and Astronautics</td>
<td>191</td>
</tr>
<tr>
<td>Department of Chemical Engineering</td>
<td>194</td>
</tr>
<tr>
<td>Department of Civil Engineering</td>
<td>197</td>
</tr>
<tr>
<td>Department of Electrical Engineering and Computer Science</td>
<td>201</td>
</tr>
<tr>
<td>Department of Materials Science and Engineering</td>
<td>207</td>
</tr>
<tr>
<td>Department of Mechanical Engineering</td>
<td>213</td>
</tr>
<tr>
<td>Department of Nuclear Engineering</td>
<td>223</td>
</tr>
<tr>
<td>Department of Ocean Engineering</td>
<td>231</td>
</tr>
<tr>
<td>Artificial Intelligence Laboratory</td>
<td>238</td>
</tr>
<tr>
<td>Biotechnology Process Engineering Center</td>
<td>244</td>
</tr>
<tr>
<td>Center for Advanced Engineering Study</td>
<td>265</td>
</tr>
<tr>
<td>Center for Technology, Policy, and Industrial Development</td>
<td>267</td>
</tr>
<tr>
<td>Center for Transportation Studies</td>
<td>269</td>
</tr>
<tr>
<td>Laboratory for Computer Science</td>
<td>275</td>
</tr>
<tr>
<td>Laboratory for Electromagnetic and Electronic Systems</td>
<td>280</td>
</tr>
<tr>
<td>Laboratory for Information and Decision Systems</td>
<td>282</td>
</tr>
<tr>
<td>Laboratory for Manufacturing and Productivity</td>
<td>291</td>
</tr>
<tr>
<td>Materials Processing Center</td>
<td>294</td>
</tr>
</tbody>
</table>

### SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

<table>
<thead>
<tr>
<th>Department</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities, Arts, and Social Sciences Office</td>
<td>191</td>
</tr>
<tr>
<td>Department of Economics</td>
<td>194</td>
</tr>
<tr>
<td>Department of Humanities</td>
<td>197</td>
</tr>
<tr>
<td>Anthropology/Archaeology Section</td>
<td>201</td>
</tr>
<tr>
<td>Foreign Languages and Literatures Section</td>
<td>207</td>
</tr>
<tr>
<td>History Section</td>
<td>213</td>
</tr>
<tr>
<td>Literature Section</td>
<td>223</td>
</tr>
<tr>
<td>Music Section</td>
<td>231</td>
</tr>
<tr>
<td>Writing Program</td>
<td>238</td>
</tr>
<tr>
<td>Department of Linguistics and Philosophy</td>
<td>244</td>
</tr>
<tr>
<td>Department of Political Science</td>
<td>265</td>
</tr>
<tr>
<td>Program in Science, Technology, and Society</td>
<td>267</td>
</tr>
<tr>
<td>Center for International Studies</td>
<td>269</td>
</tr>
<tr>
<td>Integrated Studies Program</td>
<td>275</td>
</tr>
<tr>
<td>Statistics Center</td>
<td>280</td>
</tr>
<tr>
<td>Women's Studies</td>
<td>282</td>
</tr>
</tbody>
</table>

### SLOAN SCHOOL OF MANAGEMENT

- Page 327

### SCHOOL OF SCIENCE

<table>
<thead>
<tr>
<th>Department</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Applied Biological Sciences</td>
<td>191</td>
</tr>
<tr>
<td>Department of Biology</td>
<td>194</td>
</tr>
<tr>
<td>Department of Chemistry</td>
<td>197</td>
</tr>
<tr>
<td>Department of Earth, Atmospheric, and Planetary Sciences</td>
<td>201</td>
</tr>
<tr>
<td>Department of Mathematics</td>
<td>207</td>
</tr>
<tr>
<td>Department of Physics</td>
<td>213</td>
</tr>
<tr>
<td>Bates Linear Accelerator</td>
<td>223</td>
</tr>
<tr>
<td>Cell Culture Center</td>
<td>231</td>
</tr>
<tr>
<td>Center for Cancer Research</td>
<td>238</td>
</tr>
<tr>
<td>Center for Space Research</td>
<td>244</td>
</tr>
<tr>
<td>Experimental Study Group</td>
<td>265</td>
</tr>
<tr>
<td>George Russell Harrison Spectroscopy Laboratory</td>
<td>267</td>
</tr>
<tr>
<td>Laboratory for Nuclear Science</td>
<td>269</td>
</tr>
<tr>
<td>George R. Wallace, Jr., Astrophysical Observatory</td>
<td>275</td>
</tr>
</tbody>
</table>
# VICE PRESIDENT IN THE OFFICE OF THE PRESIDENT
AND SECRETARY OF THE CORPORATION

<table>
<thead>
<tr>
<th>Department/Office</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office of the Vice President</td>
<td>393</td>
</tr>
<tr>
<td>Affirmative Action/Equal Opportunity</td>
<td>393</td>
</tr>
<tr>
<td>Office of Admissions</td>
<td>395</td>
</tr>
<tr>
<td>Educational Council</td>
<td>396</td>
</tr>
<tr>
<td>Department of Athletics</td>
<td>398</td>
</tr>
<tr>
<td>Campus Information Services</td>
<td>399</td>
</tr>
<tr>
<td>Career Services and Preprofessional Advising</td>
<td>406</td>
</tr>
<tr>
<td>Medical Department</td>
<td>412</td>
</tr>
<tr>
<td>MIT Press</td>
<td>414</td>
</tr>
<tr>
<td>Personnel Office</td>
<td>418</td>
</tr>
<tr>
<td>Quarter Century Club</td>
<td>423</td>
</tr>
<tr>
<td>Secondary Technical Education Project</td>
<td>427</td>
</tr>
<tr>
<td>Office of the Secretary of the Corporation</td>
<td>430</td>
</tr>
</tbody>
</table>

* * *

| Committee on the Visual Arts                          | 435  |
| Council for the Arts                                   | 440  |

# VICE PRESIDENT FOR FINANCIAL OPERATIONS.

| Office of the Comptroller                             | 443  |
| Office of the Director of Finance                     | 446  |
| Office of Purchasing and Stores                       | 449  |
| Office of Registration and Student Financial Services | 450  |
| Office of Sponsored Programs                          | 451  |

# VICE PRESIDENT FOR INFORMATION SYSTEMS

# SENIOR VICE PRESIDENT.

| Campus Activities Complex                             | 475  |
| Campus Police                                          | 476  |
| Endicott House                                         | 477  |
| Graphic Arts and Audio Visual Services                 | 478  |
| Housing and Food Services                              | 479  |
| Office of Facilities Management Systems                | 480  |
| Physical Plant Department                             | 481  |
| Planning Office                                        | 482  |
| Safety Office                                          | 483  |

# VICE PRESIDENT AND TREASURER

# ALUMNI ASSOCIATION
MIT is an institution with an unusual dedication and commitment to the future. At any point in our history, it is fair to say that our horizons have been in the next century. We have been enormously successful in gathering together the resources -- the people, funding, and facilities -- that have enabled us to create a great research university, one with the confidence, the enthusiasm, the concerns, and the ability to invent new fields of inquiry and educate generations of students who have helped to shape the course of science, technology, and society.

We have done so on the strength of our vision, on the talents of our faculty and students, on the confidence that our enterprise is built on and will lead to the best. This is a remarkable legacy and foundation for the future. But we need to strengthen that foundation. We need, quite frankly, to build up our own capital base so that our faculty and students have the independence, the flexibility, and the opportunity to act -- and to be -- at their very best.

In the past year, we have mobilized ourselves for the greatest fundraising drive in MIT history. We call it the Campaign for the Future. In describing the Campaign in this way, we are speaking not just of the future of MIT. We are speaking about the future of a world that the people of MIT will help create.

Our challenge, as we chart our future course, is to set our priorities and forge educational and research programs that will lead to a better world. This Campaign rises directly out of an Institute-wide effort to define our goals and focus even more sharply an educational offering that is already, we are convinced, one of the world's finest. Over the last several years, we have examined the effectiveness of our educational and research programs. Academic departments throughout the university have prepared five-year plans, with special emphasis on fields offering greatest promise for intellectual breakthroughs and social influence. Faculty and students have worked together in a major examination of the undergraduate educational program.

This kind of activity is not new to us. MIT has never been content with a static definition of its role. This was true when William Barton Rogers established a new kind of school in the 1860s and when Karl Taylor Compton led in the rebuilding of MIT as a scientific university in the 1930s and 1940s. Throughout our history, MIT has been determined to lead, not only in raising the standards of the engineering and architectural professions, but also in rebuilding the social sciences and pressing the search for scientific knowledge and the exploration of its implications for humanity.

This leadership has been called on repeatedly in the service of the nation and the world. At no time has this leadership been as needed, as relevant, as it is now -- when we face some of the most dramatic medical, economic, environmental, and political challenges and opportunities the world has ever known.

Central to our effectiveness is the excellence of our undergraduate education. The young men and women who come here as students, after all, are the future. Our hope for the future rests as surely with them -- and with what they learn here -- as it does with the discoveries and advances in knowledge that our faculty produce.

As we consider the challenges ahead, we ask, "What sets MIT apart?" The answer is that MIT has become a science-based university that places special emphasis on undergraduate education. And it is a university in which faculty and students are partners in the academic enterprise. These partnerships have created an atmosphere, a dynamic, a way of working, that stimulates innovation and the evolution of ideas. There is a sense of fire and bite and excitement that comes from laboring with, and playing with, ideas. At MIT, learning is something that goes on all the time -- in corridors, in classrooms, in research labs, in dining halls, on the playing fields. It does not go just one way, from teacher to student. We are all learners here -- generations of learners in partnership, tugging at the edges of the known universe, speeding the process of innovation through new ways of seeing and understanding the world, through new ideas and new applications.

In such an environment, the goals of our Campaign are not the end, but the means to the end. The Campaign will distill and intensify the spirit and the culture that pervade life at MIT. It is an extraordinary culture, dominated by a sense of challenge and opportunity. Marking every faculty member or student who is, or has been, a part of this place is a sense of the possible. There is the expectation that you can do your best, that you will do your best, because you are challenged here to reach higher and further, to think more rigorously, to probe more deeply, to question more critically ... not only to solve the problems but to shape the issues.
To build on the excellence of this unique environment is our touchstone, and it is the fundamental goal of our Campaign for the future. This Campaign, like this university, leads from strength. We go forward with the confidence that comes from constant renewal.

A Time of Renewal in Research and Education

Why does this seem such an auspicious time to take a searching look at our educational and research programs? The answer lies partly in the evolving nature of knowledge -- of the changing contours of the intellectual map, so to speak -- and in the nature of the issues and problems that our graduates will encounter once they leave here.

This report will discuss some of the reasons and some of the ways that MIT is addressing the challenges facing research and education as we stand on the threshold of the next century. From the beginning, MIT's faculty have known that science and technology live in society, not apart from it. Indeed, the continuing conversation between technical capabilities and human needs may well be the essence of MIT. This idea was at the heart of Rogers's founding concept of a new kind of university, and it has informed the development of the Institute for more than a century. It is the impetus for the current spirit of renewal in our research and educational programs.

There is little argument that science and technology have made major contributions to human welfare, particularly in the United States. Although opportunities are not yet available to all, ours is a wealthy country, rich in natural resources and people and education, and rich in the technical boldness and entrepreneurial skill that are essential for us to make the most of what we have. Americans have, in fact, set an example to the world by fostering research and development for continual advances in productive efficiency and material well-being. The people of MIT -- its faculty and graduates -- have been central to this technical progress and its attendant advances in economic security, health, and social well being.

And yet, over the past quarter century, there have been growing concerns over the present and future place of science and technology in our society. And there are concerns about the ways new knowledge can serve a world still beset with hunger and strife. These concerns have been expressed in many ways. There has been skepticism over whether we can use technological advances in a socially and environmentally responsible manner. There has been an alarming decline in scientific literacy in this country. There has been doubt that this country still has the edge in rapidly and successfully translating technological advances into economic advantage.

These concerns underline the fact that the development of technology has become much more complex and proceeds at a much greater pace than in the past. The definition of problems, the nature of the inquiry itself, requires partnership and collaboration among individuals from several fields from the very beginning. When it comes to such areas as biotechnology, the development of new materials, or the remaking of the industrial economy, it is no longer enough for the engineer to look to the scientist for a menu of new ideas that may hold interesting potential applications. It is no longer enough, if it ever was, for the university to stand alone in defining and working on such major problems.

There is a need for a new paradigm: a synthesis that requires understanding and cooperation among people from various disciplines and institutions and points of view. At the technical level, this interdisciplinary imperative signals a blurring of the historical distinctions between science and engineering. Beyond that, there is a need to reconcile technical considerations with considerations of the economic, political, social, and environmental impact in a fundamental way. To do this successfully, we in the academy must look to and learn from our colleagues in business and industry, in other social and cultural institutions, and in government as well.

This new paradigm holds implications for both the research and the teaching programs at MIT. It is a model that fits this place well, given our long tradition of identifying new fields and creating new working partnerships across older intellectual and institutional boundaries. Indeed, MIT may well be better suited to pursue this model than any university in this country.

Implications for Research

Over the past several years, MIT faculty have been engaged in intensive planning of long range research agenda. One of the most exciting aspects of the Campaign is the development of a number of new research initiatives that will be made possible by the availability of additional resources. These initiatives are being shaped in many domains, in areas as diverse as materials, manufacturing, the brain sciences, and housing.

For example, in the broad area of materials, almost everything we use -- from automobiles to electricity to pharmaceuticals to medical prosthetics -- involves the intricate cooperation of many types of materials. Understanding the processing and function of these materials draws on fundamental knowledge of physics, chemistry, and biology, and of manufacturing and process
engineering. Moreover, it requires a new level of cooperation between faculty and students in many fields, as in our new polymer science and technology program, where faculty in the Schools of Science and Engineering are developing a new interdepartmental graduate education and research program that builds on -- but goes beyond -- our traditional strengths in polymer research activities. What they learn and what they create will affect our communications, our transportation, our comfort, and our health.

In another area, manufacturing, it is widely recognized that US industry must undergo rapid changes in the next few years if this country is to remain economically viable. Here again, new paradigms are needed. Faculty in the Schools of Engineering and Management are committed to developing a major educational program in which manufacturing leaders will acquire both managerial and technical expertise, and the ability to operate manufacturing companies as integrated systems that can respond quickly to changes in the economic, political, social, and technological environment. We have taken the first steps with our management of technology program, but are seeking partnerships with our colleagues in industry to pursue the more ambitious agenda of rethinking the entire manufacturing process -- from planning and product design through production, management, and marketing.

In activities that involve the Schools of Science, Architecture and Planning, Humanities and Social Science, Engineering, and Whitaker College, faculty are seeking new ways to understand the human mind. Studies of nerve function, the nature of sensation and perception, and the physical basis of consciousness are being combined with new insights from artificial intelligence to understand the "programs" that the brain runs, and the kinds of computation required to run them. Other pioneering areas include the study of language acquisition by children and the possibility of a genetically determined language faculty of the mind, studies of the delicate and sophisticated chemical balances in the brain, and construction of sophisticated robotic arms and hands in order to understand better how the brain controls motion.

And, finally, individuals from planning, architecture, building construction, economics, government, industry, social planning, and other backgrounds of expertise are being drawn together to tackle one of the most perplexing problems America faces today -- housing. Recent MIT research, for example, predicts that the number of poor families without adequate and affordable housing will grow from a present 3.5 million to more than 7 million by the year 2002 as the result of economic and policy changes set in motion by tax reform and deregulation, among other factors. Beyond that, affordable housing is increasingly beyond the reach of many middle income Americans. The MIT Housing Policy Project, conducted through the Department of Urban Studies and Planning and the Center for Real Estate Development, is exploring such fundamental issues as the role of government programs and regulations in housing production and availability, the demographics of housing, new construction technologies, and the homeless and housing. The goal is nothing less than the formation of new housing policies for the nation.

Many of the initiatives being planned in these and numerous other fields are built on MIT's tradition of interdisciplinary collaboration. They reflect the emerging model of even greater synthesis and integration among various fields. Their roots are in the activities of faculty members across the Institute who have seen the need to address some old problems in new ways, or who have identified wholly new research issues requiring new approaches.

Clearly, in a research environment as diverse and vibrant as MIT's, the themes of materials, manufacturing, and the human mind do not begin to embrace the range of research agenda that are taking shape. And these agendas themselves do not cover the entire challenge of scholarship and research at MIT. As we move forward in new directions, we must preserve the quality and integrity of our core strengths in engineering and science, in the humanities and social sciences. Basic disciplinary research and scholarship have been and will continue to be one of the underlying strengths of MIT.

Nonetheless, some of the new directions being pursued here by faculty, students, and research staff are indications of an exciting future for this institution, and of significant and long term contributions to the larger society. Both content and boundaries of fields are being redefined. Perhaps most importantly, these areas of interest hold as much promise for our educational programs as they do for our research agenda: they draw on that quintessential MIT spirit of partnership between faculty and students of all ages.

That spirit was summed up by one of our senior faculty, who recently said:

"It's an incredibly exciting time to be at MIT, because there is so much going on here that is at the cutting edge. The sense of potential and opportunity is all-pervasive, with faculty and students sharing in the process of discovery. In fact, several of my most exciting research projects originated in an idea that a student brought to me and that we developed together. Our goal in educating students is not to turn out people who will reproduce the past, but people who will break new ground, make new discoveries, and set the pace for the future."
This spirit and these few examples illustrate the enormous potential that research at MIT has for making contributions of major significance to our own lives, and generally to our economy and society.

Implications for Education

It is somewhat arbitrary, in discussing education at MIT, to separate that discussion from consideration of the research agenda. Students at every level, after all, are partners in the research enterprise, and the research and scholarly activities of the faculty find their way quickly into the curriculum. Indeed, it is fair to say that everything that goes on here -- in the classroom and in the laboratory -- is education. That is what our faculty and students are doing: learning.

Nonetheless, there are aspects of education here, particularly at the undergraduate level, that stem from a primary concern for educating the whole person, not solely the future professional. The independent, questioning, problem-solving habits of mind that are solidified and burnished by an MIT education require engagement with a broad, complex, and changing set of facts and ideas. The young men and women who come to us leave here as citizens of the world, and the education we offer should enable them to move in that world as creative, sovereign human beings. If MIT is to achieve its full potential in this regard, we must continually review and redefine the meaning of a liberal education based on science.

Our work in educational renewal during the past two years has been based on the same premise as our examination of MIT research: our educational program must be better able to integrate different perspectives and approaches to learning, and be more attentive to the human contexts for scientific and technological endeavor. Clearly, the faculty does not hold a single or unified view as to what constitutes an ideal MIT education. And yet, faculty and students from virtually every department are coming together to ask hard questions about education at MIT -- what to preserve, what to transform, what to create.

There is no escaping the fact that educational renewal is a difficult task, and we are conscious that we must not try to fix something that doesn't need fixing. At the same time, it has been a quarter century since the last large-scale and detailed review of the undergraduate program. Professor Jerrold Zacharias and members of the Committee on Curriculum Content Planning would have been the first to say that the future of science-based education is, like everything else, not what it used to be.

It seemed, therefore, appropriate to take another look. Curriculum reform, however, may not be the right label for the initiatives now underway. After all, the core requirements are already in place. They express a certain integrity and commitment to intellectual scope and depth and breadth. And I think we can take pride in the fact that an MIT undergraduate is expected to engage in a range of intellectual endeavor exceeding that of many of the great liberal arts universities. The challenge, therefore, is not so much one of reform, but of renewal. We need to assess and establish a new balance between the general and specialized aspects of the educational program. Within the core general education, we need to establish a new relationship between the humanities, social sciences (including management) and the arts on the one hand, and the sciences, mathematics, and technology on the other.

Beyond that -- and here is the real challenge -- we need to develop a true educational partnership among scientific, technological, artistic, social, and humanistic disciplines. This educational synergy cannot be addressed piecemeal by individual faculty members in separate disciplines.

The Review of Undergraduate Education: A Progress Report

This reassessment had important beginnings in the School of Engineering, where faculty have been concerned with the effectiveness of undergraduate engineering education for the 21st century, and in the School of Humanities and Social Science, where there is interest in taking fuller advantage of and contributing more fully to the unique character of an MIT education and the unique interests and capabilities of MIT students.

But faculty throughout the Institute have participated in this endeavor. This past year, the three Schools with major responsibilities in undergraduate education brought forth searching reports specifying changes and improvements. The reports came from the Commission on Engineering Undergraduate Education, from the Science Education Committee, and from the Institute Committee on the Humanities, Arts and Social Sciences Requirements.

Under the leadership of the faculty Committee on the Undergraduate Program, these separate perspectives gained the attention of the entire MIT community and began to converge. Emerging from the ideas in these reports, and from spirited community-wide debate and counterproposals, is a conception of a special breed of general education -- an education that is MIT's own in definition and purpose.
The emerging common theme in faculty debate and committee work during this past year was a concept of a science-based liberal education. This concept recognizes and articulates MIT's tradition of equal commitment to science, mathematics, and technology on the one hand, and, on the other, to the humanities, arts, and social sciences -- as expressed in the General Institute Requirements. This tradition is the foundation for taking the next steps toward integrating the components of the general undergraduate program.

Some of the next steps have been taken already:

- **Humanities.** This past year the faculty voted a deceivingly modest change in the formulation of the Humanities, Arts, and Social Sciences Requirement, a component of the General Institute Requirements. The vote reaffirmed a commitment to the idea that concentration in one area and some degree of exposure to several areas was important. But the faculty also voted specific changes in the Distribution portion of the requirement. First, the previous formulation of categories of study in terms of traditional disciplines was swept away and replaced by five integrative categories emphasizing major themes cutting across disciplines. The categories are: Literary and Textual Studies; Language, Thought, and Value; The Arts; Cultures and Societies; and Historical Studies. Second, the explicit inclusion of the Arts as a category within the new framework represents a significant commitment by MIT to formal offerings in this area for our students. Third, the new Distribution subjects must be fundamental, that is, suitable for students who might never have another formal immersion in a given category of study.

- **Minors.** A second faculty action taken this year has potentially larger impact. For the first time in MIT history, the faculty established a provision for students to minor in an area of study. While the vote was specifically to provide for this option in the humanities, arts, and social sciences, we are likely to see similar provisions for minors in the sciences and possibly engineering and management in the course of time. Especially notable is the fact that this proposal was developed and accomplished through a partnership between the Schools of Engineering and of Humanities and Social Sciences. The Minor encourages and recognizes students who achieve a depth and rigor in one of the fields in humanities, arts, or social sciences that goes beyond the 8-subject minimum in the General Institute Requirements.

- **Engineering.** Last year, the School of Engineering Commission on Undergraduate Education adopted a set of goals for the education of every student majoring in engineering at MIT, goals which could easily apply to the definition of a successful undergraduate education for any student here. In brief, the Commission concluded that with such an education, a student should have:
  - acquired a firm foundation in the sciences basic to his or her field,
  - begun to acquire a working knowledge of current technology,
  - begun to understand the diverse nature and history of human society,
  - acquired skills and motivation for continued self-education,
  - had the opportunity to participate in a research project,
  - had the opportunity for engineering synthesis on a design project,
  - developed oral and written communication skills, and
  - begun to understand and respect the economic, managerial, political, social, and economic issues surrounding technical development.

The School is continuing its work on assessing its undergraduate program, and these goals are informing the work on the larger review of undergraduate education at MIT.

The School of Engineering has also started a large-scale examination of the time demands of every engineering subject. Each instructor's subject is rated by students, with the results reviewed by department heads and by the School Council for possible action. The aim is to eliminate inappropriate demands, given the overall goals and objectives of the undergraduate program.

- **Bridging.** An MIT-style liberal education is likely to require specifically designed "bridging" or integrative experiences for all undergraduates. Such subjects would bring home to students the complexities, profundities, and interrelationships of the human contexts in which science and technical pursuits take place. All three curricular reports demonstrated excitement and commitment to the development of such experiences. Integration among fields cannot happen spontaneously, however. In order to come to some common view of the nature of bridging experiences and their role in the overall four year program, we have embarked on a major curriculum development effort involving approximately 50 faculty from all five Schools. These faculty members are developing prototype integrative academic experiences for students. Three prototype efforts have been
winnowed from this work to date and have been launched as accredited new subjects to be taught by teams of faculty from different schools.

- **Faculty minicourses.** These bridging experiences are extremely difficult to develop and to mount. They require, first, that our faculty themselves have such academic experiences to draw on. The mechanism for doing this is a series of interdisciplinary minicourses for faculty, taught by faculty members. The first examples, in the past two summers, have been judged extremely effective. In the summer of 1986, the School of Engineering faculty hosted and ran an intensive one week introduction to the structure and interpretation of computer programs for 30 faculty members from the School of Humanities and Social Science. That School reciprocated with a minicourse on the frontiers of modern molecular biology, organized by the Biology faculty. A minicourse focusing on the epic in its ancient and modern guises, taught by the Literature faculty, was attended by faculty from all five Schools. More than 10 percent of the Institute's faculty attended these cross-School minicourses this past June.

- **Environment for Living and Learning.** As I reported last year, we are also developing some new programs to enhance the environment for living and learning at MIT, with a particular emphasis on encouraging more informal intellectual contact between students and faculty members. These activities include the creation of freshman seminars taught by faculty to their advisees, seminars in living groups, and advising clusters organized by living group. Particularly successful was the advisor-led seminar; we increased that program from eight to 33 seminars this fall, and still were unable to meet the demand.

Also in the past year, we received the report of a faculty committee to review the housemaster-graduate resident system. This committee, chaired by the Dean of Engineering, made a number of recommendations for strengthening the residential program, including a proposal for an MIT House Fellows Program, the goal of which is to promote greater interaction between students in Institute Houses and MIT faculty through a variety of informal non-academic activities. Under this program, which begins this coming year as a three-year experiment, each participating House will have five or six faculty House Fellows who will contribute to the intellectual and social life of the House through a variety of activities such as dramatic productions, athletic events, policy debates, musical performances or outings, or literary readings. In general, the role of the House Fellow would be to complement more formally academic House-based activities, such as the House seminars and team advising for freshmen.

During this coming year, a special faculty committee will study the first-year academic program. It will probe the academic experience and structure of that first year for all entering undergraduates. The aim is to provide a more intellectually invigorating and enabling first year. The freshman year is crucial because it establishes the student's view and understanding of the intellectual style and values of the academic community he or she has joined. MIT can do better in the first year than it has been doing. And so, the Committee on the First-Year Program will focus on the intellectual community, the calendar, the intensity, and the pathways through the freshman year.

Also in the coming year, faculty will focus on the science, mathematics, and technology component of MIT's core general education. Faculty deliberations so far point toward the need for an even stronger science foundation for our students. Although the extraordinary quality of MIT's life sciences faculty is widely recognized as the best in the country, if not the world, our requirements in science, mathematics, and technology do not contain the expectation that all undergraduates should be introduced to this area of knowledge.

MIT's assessment of its already strong core in science, mathematics, and technology comes when liberal arts colleges across the country are trying to strengthen and extend their typically meager science core, to create a program similar to that which has been traditional here. In these times, MIT's leadership in creating a balanced liberal education -- containing more science, a renewed emphasis on the humanities, arts, and social sciences, and, potentially, integrative "contexts" courses -- may have a broad impact on American education.

---

These are but a few of the steps that we are taking along the path of educational renewal. Most of these steps have been taken by the faculty. Our success, however, will depend fully as much on the quality and character of our students as it does on the initiatives of our faculty. And perhaps the most dramatic progress in the process of educational renewal has taken place in Admissions. Our primary goal, of course, remains unchanged: to bring to MIT the most academically promising and interesting students with strong backgrounds in mathematics and science. We are, however, seeking more such students whose intellectual interests reach beyond science and engineering. In addition, we have been seeking to increase the percentage of women and minorities in our entering classes.
I can report progress on all fronts. Over the past two years, we have developed and begun to use a new system to evaluate applicants, we have embarked on a much more extensive school visits program, we have redesigned our recruiting publications, we established a new reception area for prospective students and their families, and we have new programs and staff to attract and support minority students.

I can also report clear indications of success. For the Class entering this fall, we had the largest number of applicants in our history -- 7,300 -- of whom we admitted 25 percent. The Class of 1991 numbers just 1,001, with 85 percent of these students coming from the top five percent of their high school classes. The Director of Admissions reports that these students are characterized by broad academic interests, wide cultural diversity, and better racial balance than any previous group admitted to MIT. Moreover, their academic strength, as measured by grades and test scores, has increased over last year's class.

Judging from those students I have met already, I would venture to say that we will be challenged by them and stimulated by them in the best possible ways, as we seek to define an MIT education for the future. The culture they create, the academic interests they express, the plurality of perspectives they bring to this campus will be central to the character and quality of education during their years here and, I believe, in the educational programs that we are framing for future generations of students.

Campaign for the future

As I mentioned at the start of this report, the intensive examination and renewal of MIT's education and research programs have prepared us all for the great five-year effort to raise $550 million. This effort is aimed at mobilizing the resources MIT needs to achieve the potentials we see opening up -- and which appear to us more as imperatives, things we must do, than merely as goals we hope to achieve.

All of us cooperating in the Campaign -- above all the donors who will be joining our great effort -- will be working together to provide the resources to give life to the visions that are taking concrete shape.

The resources we shall be mobilizing will reinforce the qualities of MIT that we cherish: the freedom, the flexibility, the trust, and the expectation that we will do our very best -- for our students, for the universe of knowledge, and yes, for the future. MIT has a pact with the future, a trust that we can make a difference in the world, a difference for the better.

What are the resources that will enable MIT to make this difference? As we fixed upon our specific goals for the Campaign, it became clear that this is a campaign for the fundamentals, for the very backbone of MIT. This Campaign is dedicated to strengthening our foundation, that is, the unique community of faculty and students that defines MIT.

And so our Campaign priorities are formulated in just those terms. In brief, they are:

- **Faculty professorships.** We need to provide increased support and flexibility for our faculty to pursue the inspired and inspiring educational and research programs that have been a hallmark of MIT.

- **Funding for new academic initiatives.** These are opening up not only within, but among, our five Schools as faculty identify the complexities and interrelationships among the most interesting and pressing issues.

- **Financial support for students.** We must be able to provide reasonable levels of financial aid so that we can continue to attract and admit the very best students, without regard to their financial circumstances.

- **Funds for new undergraduate academic programs and for campus activities.** A more complete undergraduate life inside the classroom and out can be one of the most important results of this Campaign.

- **Facilities.** A new science complex, including new or renovated quarters for Biology, Physics, and Applied Biological Sciences, is our primary academic facilities goal. And housing for graduate students, long on our agenda, is an imperative for a research university of our calibre.

- **General Endowment.** Increasing our general endowment is a particularly high-priority goal. The income from such endowment provides the kind of financial flexibility and independence that allows us to seize the moment of opportunity in both education and research.

Participation of all -- faculty, administration, alumni, trustees -- is crucial to the success of the Campaign. The continuing study and discussions that have sparked the new activities in our education
and research programs to date was essential in defining the goals for our drive. But they also bring us to the start of this effort with significant steps already achieved, and others in process. This in turn strengthens our confidence just when we need it most: on the eve of making our case to the world that the Campaign for MIT is the Campaign for the future.

PAUL E. GRAY
September 1987
In Special Recognition

The special character of MIT is highlighted every year in the achievements and honors of its faculty. While it is not possible to take note of every such distinction, there are some highlights which deserve mention.

In the spring the National Academy of Engineering elected three members of the MIT faculty to membership in the National Academy of Engineering. New MIT members are: Amar G. Bose and Alan V. Oppenheim, both Professors of Electrical Engineering and Computer Science, and Yao Tzu Li, Professor Emeritus and Senior Lecturer, Department of Aeronautics and Astronautics.

This past year two members of the faculty were elected members of the National Academy of Sciences. Those new MIT members are: Hermann A. Haus, Professor of Electrical Engineering and Computer Science, and Harvey F. Lodish, Professor of Biology.

Eight members of the MIT faculty were among those elected as Fellows of the American Academy of Arts and Sciences. New MIT members elected to the Mathematical and Physical Sciences section are: Albert R. Meyer and Joel Moses, Department of Electrical Engineering and Computer Science; Robert J. Birgeneau and Alan Guth, Department of Physics; and Satoru Masamune, Department of Chemistry. Elected to the Biological Sciences section are: Paul R. Schimmel and Alexander Varshavsky, Department of Biology. Elected to the Humanities section is John Harbison of the Music Section of the Department of Humanities.

Ioannis V. Yannas, Professor of Polymer Science and Engineering in the Department of Mechanical Engineering, was one of 40 new members elected to the Institute of Medicine.

Har Gobind Khorana, Alfred P. Sloan Professor of Biology and Chemistry, was among the 20 persons who received the National Medal of Science in June 1987. Dr. Khorana received the Medal of Science for his "innovative contributions that significantly contributed to our understanding of gene structures, membrane function and vision."

In November Margaret L. A. MacVicar, Dean for Undergraduate Education, was awarded one of two 1986 Charles A. Dana Foundation prize for "conceiving, designing and implementing" MIT's Undergraduate Research Opportunities Program. The Foundation presented the awards for the first time this year for achievement in the fields of health and higher education.

John Harbison, Professor in the Music Section, was awarded the 1987 Pulitzer Prize for musical composition in April 1987. He was recognized for his cantata "The Flight Into Egypt."

An Alexander von Humboldt Senior U.S. Scientist Award and a Max Planck Society Award were presented to Brian J. Clifton, staff member in the Microelectronics Group at Lincoln Laboratory. The Humboldt awards are granted to outstanding U.S. scientists in recognition of accomplishments in research and teaching.

Bruno B. Rossi, Institute Professor and Professor of Physics, Emeritus, was named a corecipient of the Wolf Prize in Physics for 1987 for his pioneering research in X-ray astrophysics. He shared the prize with Riccardo Giacconi of Johns Hopkins University and Herbert Friedman of the Naval Research Laboratory for their discovery of extra solar X-ray sources and related research.

Within the Institute, Hermann A. Haus, Elihu Thomson Professor of Electrical Engineering, was named an Institute Professor. The title of Institute Professor is an honor bestowed by the faculty on a colleague for leadership and distinguished accomplishments in the scholarly, educational, and general intellectual life of MIT and the wider academic community. Professor Haus has distinguished himself as both a scientist-engineer and teacher, praised by his colleagues for "his gift of bringing understanding to whatever he undertakes; his elegant theoretical formulation, lucid physical insight and thoroughness of approach; and the depth, sophistication and integrity of his research."

Jay W. Forrester, Germeshausen Professor of Management, was selected as the 1987-88 recipient of the James R. Killian Jr. Faculty Achievement Award. Established in 1971 as a tribute to Dr. Killian, MIT's tenth President and former Chairman of the Corporation, the award recognizes extraordinary professional accomplishments and service to the Institute. The committee's citation said in part: "Jay is a pioneer. He is one of those rare individuals who possess not only the intellect and imagination to see the path ahead, but the skill and the stamina to lead the journey."
In the late spring, Sylvia T. Ceyer, Assistant Professor in the Chemistry Department, was named the 1987 recipient of the Harold E. Edgerton Faculty Achievement Award. The award is given annually to a junior faculty member who has made outstanding contributions in research, teaching and service to the MIT community. The selection committee in its citation noted that she is "an accomplished scholar and a talented and innovative experimentalist."

This past year several key leadership roles at the Institute changed, and those transitions were occasion for special recognition.

Lester C. Thurow, Gordon Y Billard Professor of Management and Economics, was named dean of the Sloan School of Management effective July 1987. He succeeds Abraham J. Siegel, who has served as dean since 1980 and is returning to teaching and research. Professor Thurow's research and writing has focused primarily in the areas of income distribution economics, public finance, and international economics.

New department or program heads appointed or announced during the past year are: Rafael L. Bras, Director, MITES (Minority Introduction to Engineering and Science) Program; Mario L. Gnecco, Director, Management of Technology Program; John H. Harbison, Head, Music Section, Department of Humanities; Arnoldo C. Hax, Deputy Dean, Sloan School of Management; James Howe, Head, Anthropology and Archaeology Section, Department of Humanities; Phillip S. Khoury, Associate Dean, School of Humanities and Social Science; Thomas L. Magnanti, Co-Director, Operations Research Center; Tod Machover, Director, Philippe Villers Experimental Media Facility; Amedeo R. Odoni, Co-Director, Operations Research Center; William L. Porter, Interim Head, Architecture; Glen L. Urban, Deputy Dean, Sloan School of Management; Myron Weiner, Director, Center for International Studies; and Mark S. Wrighton, Head, Department of Chemistry. Bernard J. Frieden, Professor of Urban Studies and Planning, was elected to head the MIT Faculty and Sallie W. Chisholm, Professor of Civil Engineering, was elected associate chairman of the faculty. Jack Ruina will continue to serve as secretary.

Major changes in the Institute's central administration during the year included the appointment of Arnold Weinberg as Medical Director and David S. Wiley as Registrar.

The Institute was saddened this year by the deaths of several longtime friends and colleagues. We miss them and are grateful for their contributions to this community.

David Adler, professor of electrical engineering and a renowned solid-state physicist, died in March of 1987 at the age of 51. Dr. Adler joined the MIT faculty in 1967 and achieved recognition for his outstanding undergraduate teaching and extensive work on the physics of amorphous semiconductors. He was widely published and was an important contributor to the development and operation of the Concourse Program at MIT.


Professor emeritus of biochemistry Bernard S. Gould died at the age of 75 in February 1987. He was a 1932 graduate of MIT. During his nearly forty years on the MIT faculty, until his retirement in 1977, he specialized in the biochemistry of wound healing, tissue regeneration, and the role of vitamins in these processes.

Ida M. Flansburgh Green died in December of 1986 at the age of 83. Along with her husband Cecil, she made extraordinary philanthropic contributions to the Institute, including the funding of numerous professorships and the Ida Green Fellowships for graduate women, and the endowing of the Green Building where the Department of Earth, Atmospheric, and Planetary Sciences is housed. Mrs. Green became a Member of the MIT Corporation in 1979 and was honored with the naming of the Ida M. Flansburgh Green Hall for graduate women in 1983. She was an honorary member in the Association of MIT Alumnae.

Edward Neal Hartley died in December of 1986 at age 72. A former member of the History faculty and head of the Institute Archives, he was on the MIT faculty for thirty-one years until his retirement in 1977.

Paul F. Hellmuth, aged 68, died in August of 1986. A member of the MIT Corporation from 1974 to 1979, he was associated with the Boston law firm of Hale & Dorr and was co-chairman of the MIT Leadership Campaign.

Elizabeth Parks Killian, wife of former MIT president, James R. Killian, Jr., died at the age of 79 in November of 1986. A 1929 graduate of Wellesley College, Mrs. Killian's enthusiastic involvement in MIT activities spanned many decades and included especially the years during her husband's terms as MIT president and as chairman and honorary chairman of the MIT Corporation.
In August of 1986 professor emeritus of the Department of Physics, M. Stanley Livingston, died at the age of 81. Professor Livingston joined the MIT faculty in 1938, built MIT's first cyclotron, and was involved in undergraduate teaching and in the design and construction of cyclotrons and high-voltage accelerators for studying atomic physics. Professor Livingston retired from the Institute in 1970.

Avery A. Morton died in March of 1987, at the age of 94. Professor Morton came to the Institute in 1920 as an instructor in organic chemistry, receiving his Ph.D. degree in 1924. In 1940 he became full professor and director of the research laboratory of organic chemistry. He retired from MIT in 1958.

Clint W. Murchison died at age 63 in March of 1987. Mr. Murchison received his S.M. degree in mathematics from MIT in 1944 and had been a member of the MIT Corporation since 1972 and a Life Member since 1977. His entrepreneurial achievements ranged from insurance and banking to publishing and professional sports, an interest which in 1960 led him to found the Dallas Cowboys.

Frederick H. Norton, a 1918 graduate of MIT in physics, died in November 1986 at the age of 90. Professor Norton was internationally recognized for setting forth the principles leading to the establishment of ceramics as an important science and authored the first standard text in this field. In 1927 Professor Norton returned to MIT to join the faculty in the Department of Materials Science and Engineering; he headed the Ceramics Division for many years and retired in 1962.

Internationally known Slavic literature scholar Krystyna Pomorska died in December 1986 at the age of 58. The author of several books and hundreds of articles, Professor Pomorska came to MIT in 1963 where she pursued her work in Slavic poetry and 19th and 20th Century Russian literature. With her late husband and former MIT faculty member, Roman Jakobson, she coauthored Dialogues, an account of Professor Jakobson's life.

Professor emeritus Brandon G. Rightmire died in January 1987 at age 75. He received the Sc.D. in mechanical engineering from MIT in 1941 and joined the MIT faculty in 1942. His interest lay in fluid mechanics, applied dynamics and thermodynamics, and he coauthored the text, Engineering Applications of Fluid Mechanics. He retired in 1976.

In April 1986 George P. Wadsworth died at the age of 78. Professor Wadsworth received the S.B. (1930), S.M. (1931), and Ph.D. degrees (1933), all from MIT, and for thirty-nine years until his retirement in 1974 served in the Department of Mathematics, making significant contributions through his work in probability and statistics to meteorological forecasting, oil exploration, and operations, medical, and ocean wave research. He authored several textbooks and was actively involved in undergraduate education at the Institute.

Zenon S. Zannetos, 59, professor of management at the Sloan School of Management, where he was affiliated for more than thirty years, died in May 1987. He completed the S.M. and the Ph.D. at MIT in 1955 and 1959, respectively, and was known for his work in oil economics. He became a member of the MIT faculty in 1961, developed and taught in the Executive Development Program at Sloan, served as Chairman of the Senior Executive Program Committee, and most recently served as Senior Associate Dean for Development.
Statistics for the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1986-87.

Registration

In 1986-87 student enrollment was 9,756, compared with 9,787 in 1985-86. This total was comprised of 4,443 undergraduates (compared with 4,541 the previous year), and 5,313 graduate students (compared with 5,246 the previous year). Graduate students who entered MIT last year held degrees from 352 colleges and universities, American and foreign. The international student population was 1,896 (not including permanent residents), representing 7 percent of the undergraduate and 30 percent of the graduate population. These students were citizens of 90 countries.

In 1986-87 there were 2,340 women students (1,295 undergraduate and 1,045 graduate) at the Institute, compared with 2,218 (1,176 undergraduate and 1,042 graduate) in 1985-86. In September 1986, 378 first-year women entered MIT, representing 38 percent of the freshman class.

In 1986-87 there were 1,344 minority students (1,124 undergraduate and 220 graduate) at the Institute, compared with 1,241 (1,047 undergraduate and 194 graduate) in 1985-86. Due to changes in Federal guidelines, the numbers for 1986-87 include students with permanent residence status; those for 1985-86 do not. Minority students in 1986-87 included 300 Blacks (non-Hispanic), 21 Native Americans, 265 Hispanics, and 758 Asian Americans. The first-year class entering in September 1986 included 302 minority students, representing 30 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1986-87 included 1,159 bachelor's degrees, 1,150 master's degrees, 42 engineer's degrees, 459 doctoral degrees — a total of 2,810.

Student Financial Aid

During the academic year 1986-87 the student financial aid program was again characterized by an increase in the overall need for financial aid and in the aggregate amount of grants made available. There was a decrease in the amount of MIT loans awarded, in the face of a significant increase in the amount of National Direct Student Loans made. Guaranteed Student Loans obtained from commercial sources showed a notable decrease.

A total of 2,360 undergraduates who demonstrated the need for assistance (53 percent of the enrollment) received $16,209,000 in grant aid and $3,610,000 in loans. The total, $19,819,000, represents a 5 percent increase in aid compared to last year.

Grant assistance to undergraduates was provided by $4,813,000 in income from the scholarship endowment, by $2,067,000 in outside gifts and Federal allocations to MIT for scholarships, and by $3,208,000 in direct grants from outside sources, including ROTC, to needy students. In addition, $6,121,000 in scholarships from MIT's unrestricted funds was provided to undergraduates, inclusive of the special program of scholarship aid to minority group students which represented $164,000 from unrestricted funds. An additional 709 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was aided by the addition of $6,284,000 in new funds, a new high that raised the principal of the endowment by 16 percent, to $46,422,000.

Loans totaling $3,610,000 were made to needy undergraduates -- a 10 percent increase from last year. Of this amount, $766,000 came from the Technology Loan Fund and $2,844,000 from the National Direct Student Loan Fund. Not included in the foregoing summary is an additional $4,834,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained $1,198,000 from the Technology Loan Fund, $357,000 of which was loaned to international students and did not qualify for the Federal interest subsidies and guarantees available under the Guaranteed Student Loan Program. In addition, $56,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, $1,254,000, represents a 17 percent decrease from last year's level. Graduate students obtained $3,350,000 from outside sources under the Guaranteed Student Loan Program -- about the same as last year. The total loaned by MIT to both graduate and undergraduate students was $4,864,000, a 2 percent increase over last year.
[Note: All of the numbers reported in this section reflect awards from the academic year perspective and so will not agree exactly with fiscal-year-based records reported by the Comptroller or the Treasurer.]

Career Services and Preprofessional Advising

Notwithstanding lean times in many industries, slow growth in others, corporate "downsizing," corporate mergers, and a leveling-off in the growth of defense spending, more companies and government agencies came recruiting than a year ago. A total of 423 employers made one or more visits, compared with 395 in 1985-86. The total in 1984-85 was slightly higher, 431. The discipline most often requested was electrical engineering, followed closely by computer science. Mechanical engineering was requested two-thirds as often as electrical engineering; chemical engineering, materials science and engineering, and aeronautics and astronautics were requested one-third as often.

While the level of recruiting activity was high, this interest was not always reflected in the number of offers reported and in salaries. For example, seniors in electrical engineering and computer science reported a third fewer offers. There were also fewer offers to master's degree candidates in aeronautics and astronautics and in chemical engineering. On the other hand, there were more offers to seniors in management. Meanwhile, salaries grew only slightly from a year ago. For example, salaries offered to seniors in electrical engineering and computer science were up less than three percent (to a median of $31,020); offers to seniors in chemical engineering were up less than two percent (to $30,480); offers to PhD physicists were up one percent (to $45,000). The highest offers were to PhD's in electrical engineering, up 6.5 percent to $51,000. It was a good year for students with computer skills. Offers to seniors in computer science (up four percent to $31,320) exceeded for the first time offers to seniors in electrical engineering.

The number of MIT applicants to medical school declined, matching a decline in the nation. They totaled 112, compared with 123 in 1985-86. They included 65 seniors, 1 graduate student, and 46 alumni. As of the first of July, 54 seniors had been accepted (83 percent), the one graduate student, and 37 of the alumni (80 percent). The overall acceptance rate at this preliminary stage was 82 percent.

Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to $882,484,000, an increase of 11 percent over 1985-86. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory -- amounted to $359,856,000 during 1986-87, compared to $332,211,000 in 1985-86. The direct expenses of departmental and interdepartmental sponsored research on campus increased from $179,648,000 to $184,526,000; and direct expenses of the Lincoln Laboratory's sponsored research increased from $280,643,000 to $338,062,000.

Current revenues used to meet the Institute's operating expenses totaled $879,384,000, augmented by $3,100,000 in unrestricted gifts. After meeting these expenses, a surplus of $1,175,000 in current unrestricted gifts was held at year-end.

The Institute made only modest additions to facilities and the book value of educational plant facilities increased from $321,581,000 to $327,408,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, students' notes receivable, and amounts due from educational plant, had a book value of $917,464,000 and a market value of $1,396,716,000. This compares to book and market values of $784,089,000 and $1,175,678,000 last year.

Gifts

Gifts, grants, and bequests to MIT from private donors increased by 25 percent in 1986-87 to $68,331,000, as compared to $54,783,000 in 1985-86. The Alumni Fund reported gifts of $13,686,000 for the year, another record.

Physical Plant and Campus Environment

This year saw the completion of the Philippe Villers Experimental Media Facility in the Wiesner Building and several successful productions were held in the space by year-end. On the West Campus, a new state-of-the-art, multi-use artificial turf playing field was installed adjacent to the J. B. Carr Tennis Facility. In addition, the Carr Tennis Facility air-supported enclosure was replaced with one having better insulating qualities, improved lighting characteristics, and a longer projected life.

New projects initiated during the year included a major renovation of the Stratton Center where a variety of retail stores, a new food court, and numerous other major changes will be introduced; the
conversion of the former Hayden Gallery in the Hayden Library to the Elizabeth Parks Killian Hall, a space where the School of Humanities and Social Science can schedule music performances, seminars, and other school functions; and renovations to the east wing of Ashdown House which, when completed, will provide living accommodations for an additional thirty graduate students. In addition, following years of study, approval was received to proceed with the permitting and preliminary design phases of a combined-cycle cogeneration facility to be located in our existing Central Utilities Plant on Vassar Street. Upon completion, this facility will generate 28 megawatts of power for sale to the local utility and produce base load campus heating steam for most of the year, thereby enabling us to take our two oldest boilers out of service. Projected savings over the life of the project are substantial.

Three land acquisitions made during the year are worthy of note, namely the purchase of the TRW property at the corner of Main and Ames Street, the F&T Restaurant and Diner, and the Cambridge Press properties in Kendall Square. These three pivotal acquisitions will now enable us to plan for an orderly expansion of our academic activities in this vital area of the campus.

A sample of programs initiated during the year that could directly affect MIT's environment include a systematic process of identifying all remaining asbestos-containing materials on campus and the identification of all remaining equipment that contains PCBs. Once these identification processes are completed, abatement programs will be initiated. In addition, the first phase of a program to identify and catalogue historical subsurface datum points including ground water survey wells and settlement pins was completed. This program, which builds on the old Foundation Experimentation Research project (FERMIT) carried out by the Soils Engineering Group of the Civil Engineering Department in the 1960s and 1970s, will provide valuable data for monitoring the condition of the 6,000 wood piles which support original campus buildings.
Personnel Changes

 TERMS EXPIRED
 David R. Clare
 Member

 Bernard W. Harleston
 Member

 David I. Kosowsky
 Member

 TERMS EXPIRED
 David R. Clare
 Member

 Bernard W. Harleston
 Member

 David I. Kosowsky
 Member

 DEATHS
 Ida M. Green
 Life Member, Emerita

 Clint W. Murchison, Jr.
 Life Member, Emeritus

 CHANGES OF APPOINTMENT
 Robert C. Gunness
 Life Member, Emeritus

 ELECTIONS
 E. Rudge Allen
 Member

 Yaichi Ayukawa
 Member

 John K. Castle
 Member

 Robert B. Horton
 Member

 Walter J. Humann
 Member

 Shirley A. Jackson
 Member

 Jerry McAfee
 Member

 F. Richard Meyer, III
 Member

 Rita A. O'Brien
 Member

 Frank Press
 Member

 Robin M. Wagner
 Member

 Dolores Wharton
 Member

 MEMBER EX-OFFICIO
 Raymond S. Stata
 President
 Alumni Association

 FACULTY
 DEATHS
 David Adler
 Department of Electrical Engineering and Computer Science

 Zeno S. Zannetos
 Sloan School of Management

 MORRIS A. ADELMAN
 Department of Economics

 WAYNE V. ANDERSON
 Department of Architecture

 ALAN H. BARRETT
 Department of Physics

 CHARLES BATTERMAN
 Athletic Department

 ROBERT L. BISHOP
 Department of Economics

 ROBERT L. COBLE
 Department of Materials Science and Engineering

 JACK B. DENNIS
 Department of Electrical Engineering and Computer Science

 MARTIN DEUTSCH
 Department of Physics

 EDMUND DIAMOND
 Department of Political Science

 MARTIN DYCK
 School of Humanities and Social Science

 HERMAN FESHBACH
 Institute Professor

 DANIEL M. HOLLAND
 Sloan School of Management

 FRANCIS F. LEE
 Department of Electrical Engineering and Computer Science

 CHIA-CHIAO LIN
 Institute Professor

 EDWARD N. LORENZ
 Department of Earth, Atmospheric, and Planetary Sciences

 RENE H. MILLER
 Department of Aeronautics and Astronautics

 PHILIP MORRISON
 Institute Professor

 WALLE J. NAUTA
 Institute Professor

 PAUL M. NEWBERNE
 Department of Applied Biological Sciences

 ASHER H. SHAPIRO
 Institute Professor

 ELI SHAPIRO
 Sloan School of Management

 LOUIS D. SMULLIN
 Department of Electrical Engineering and Computer Science

 CHESTER L. SPRAGUE
 Department of Architecture

 C. GARDNER SWAIN
 Department of Chemistry

 GEORGE WOLF
 Office of the Provost

 RESIGNATIONS
 Professor

 MERRILL F. GARRETT
 Department of Brain and Cognitive Sciences

 CLARK GRAHAM
 Department of Ocean Engineering
R. Alan North  
Department of Applied Biological Sciences

Peter H. Smith  
Department of Political Science

Associate Professor

Katharine G. Abraham  
Sloan School of Management

Charles Alcock  
Department of Physics

Bernard Avishai  
Writing Program

Anders Bjorner  
Department of Mathematics

James G. Branson  
Department of Physics

Bernard C. Levy  
Department of Electrical Engineering and Computer Science

Michael A. Marletta  
Applied Biological Sciences

Frank Morgan  
Department of Mathematics

Steven Mullaney  
Literature Section

Alan C. Nelson  
Department of Nuclear Engineering

Terry A. Ring  
Department of Materials Science and Engineering

Robert J. Slattery  
Department of Architecture

Brian H. Smith  
Department of Political Science

Deborah A. Stone  
Department of Political Science

Scott D. Tremaine  
Department of Physics

Bruce K. Walker  
Department of Aeronautics and Astronautics

William D. Whiddon  
Department of Ocean Engineering

Gary E. Wnek  
Department of Materials Science and Engineering

Richard E. Zippel  
Department of Electrical Engineering and Computer Science

Asstistant Professor

John M. Abowd  
Department of Economics

Robert E. Bayliss  
Athletic Department

Judith W. Decew  
Department of Linguistics and Philosophy

Antonio L. Elias  
Department of Aeronautics and Astronautics

Richard K. Helling  
Department of Chemical Engineering

Charles J. Horowitz  
Department of Physics

Sudhir Krishnamurthi  
Sloan School of Management

Denis F. Simon  
Sloan School of Management

PROMOTIONS

To Professor

John L. Buttrick  
Music Section

Sallie W. Chisholm  
Department of Civil Engineering

Elzbieta E. Chodakowska  
Writing Program

Joel P. Clark  
Department of Materials Science and Engineering

Henry S. Farber  
Department of Economics

Michael W. Golay  
Department of Nuclear Engineering

Alan Guth  
Department of Physics

Gary A. Hack  
Department of Urban Studies and Planning

H. Robert Horvitz  
Department of Biology

Mujid S. Kazimi  
Department of Nuclear Engineering

Nancy A. Lynch  
Department of Electrical Engineering and Computer Science

Gregory A. Petsko  
Department of Chemistry

Frank Solomon  
Department of Biology

John B. Southard  
Department of Earth, Atmospheric, and Planetary Sciences

Harry L. Tuller  
Department of Materials Science and Engineering

Alexander Varshavsky  
Department of Biology

Eric A. Von Hippel  
Sloan School of Management

Graham C. Walker  
Department of Biology

To Associate Professor

David J. Anick  
Department of Mathematics

Robert C. Berwick  
Department of Electrical Engineering and Computer Science

Anders Bjorner  
Department of Mathematics

John M. Essigmann  
Department of Applied Biological Sciences

Edward H. Farhi  
Department of Physics

Michael E. Geisler  
Foreign Languages and Literatures Section

Ahmed F. Ghoniem  
Department of Mechanical Engineering
Lance A. Glasser  
Department of Electrical Engineering and Computer Science

Philip M. Gschwend  
Department of Civil Engineering

Timothy G. P. Gutowski  
Department of Mechanical Engineering

Robert J. Halstead, Jr.  
Department of Electrical Engineering and Computer Science

Nabeel Hamdi  
Department of Architecture

John Hildebidle  
Literature Section

Gretchen Kalonji  
Department of Materials Science and Engineering

Paul A. Lagace  
Department of Aeronautics and Astronautics

Michael A. Marietta  
Department of Applied Biological Sciences

Marcia K. McNutt  
Department of Earth, Atmospheric, and Planetary Sciences

Ralph L. McNutt, Jr.  
Department of Physics

Silvio Micali  
Department of Electrical Engineering and Computer Science

Steven Mullaney  
Literature Section

Richard C. Mulligan  
Department of Biology

James M. Poterba  
Department of Economics

John Sterman  
Sloan School of Management

Sharon Traweek  
Anthropology/Archaeology Program

Bruce K. Walker  
Department of Aeronautics and Astronautics

P. Timothy Walsh  
Athletic Department

D. Eleanor Westney  
Sloan School of Management

CHANGES OF APPOINTMENT

E. Daniel Blankschein  
Texaco-Mangelsdorf Assistant Professor  
Department of Chemical Engineering

Robert A. Brown  
Arthur Dehon Little Professor  
Department of Chemical Engineering

Steven J. Burden  
Thomas D. and Virginia W. Cabot Career Development Assistant Professor  
Department of Biology

Steven R. Bussolari  
Charles Stark Draper Assistant Professor  
Department of Aeronautics and Astronautics

Peter P. S. Chen  
Donald B. Sinclair Visiting Professor of Computer Science  
Department of Electrical Engineering and Computer Science

John C. Cox  
Nomura Professor of Finance  
Sloan School of Management

William J. Dally  
ITT Career Development Assistant Professor of Computer Science  
Department of Electrical Engineering and Computer Science

Richard Eckaus  
Department Head/Professor  
Department of Economics

Stanley Fischer  
Associate Department Head/Professor  
Department of Economics

Robert M. Freund  
Elisha Gray II Career Development Assistant Professor of Management  
Sloan School of Management

David K. Gifford  
KDD Career Development Assistant Professor of Communication and Technology  
Department of Electrical Engineering and Computer Science

Michael B. Giles  
Charles Stark Draper Assistant Professor  
Department of Aeronautics and Astronautics

Deborah L. Gladstein  
Assistant Professor of Organizational Studies  
Sloan School of Management

Kenneth Keniston  
Director and Professor  
Program in Science, Technology and Society

Tunney F. Lee  
Department Head  
Department of Urban Studies and Planning

Andreas Mortensen  
ALCOA Assistant Professor  
Department of Materials Science and Engineering

Rosemary L. Smith  
Donald B. Sinclair Visiting Assistant Professor of Electrical Engineering  
Department of Electrical Engineering and Computer Science

Ulrich W. Suter  
Bayer Associate Professor  
Department of Chemical Engineering

George C. Verghese  
Carl Richard Soderberg Associate Professor of Electrical Engineering  
Department of Electrical Engineering and Computer Science

NEW FACULTY APPOINTMENT

Professor

Claire Kramsch  
Professor of Foreign Language Acquisition  
Foreign Languages and Literatures Section

Haynes R. Miller  
Department of Mathematics
Barrick F. Tibbitts  
Department of Ocean Engineering  
Associate Professor

Edward H. Adelson  
Department of Architecture

Richard A. Andersen  
Department of Brain and Cognitive Sciences

Peter L. Hagelstein  
Associate Professor of Electrical Engineering 
Department of Electrical Engineering and Computer Science

Alex Paul Pentland  
Department of Architecture

Barry R. Posen  
Department of Political Science

Marc H. Raibert  
Department of Electrical Engineering and Computer Science

Paul E. Sullivan  
Associate Professor of Naval Architecture 
Department of Ocean Engineering

Mriganka Sur  
Department of Brain and Cognitive Sciences  
Assistant Professor

Edith K. E. Ackermann  
Department of Architecture

Christopher G. Atkeson  
Department of Brain and Cognitive Sciences

Edmund W. Bertschinger  
Department of Physics

Ravi Bhushan  
Assistant Professor of Management 
Sloan School of Management

Stuart Brown  
Department of Materials Science and Engineering

Luis G. Casian  
Department of Mathematics

Peter Child  
Music Section

George Chryssolouris  
Department of Mechanical Engineering

Michael J. Cima  
Department of Materials Science and Engineering

Susan Cooper  
Department of Physics

Michael A. Cusumano  
Assistant Professor of Management 
Sloan School of Management

William J. Dally  
Department of Electrical Engineering and Computer Science

Jeffrey L. Feerer  
Assistant Professor and Station Director 
Department of Chemical Engineering

Kenneth A. Froot  
Assistant Professor of Management 
Sloan School of Management

Mark D. Haiman  
Assistant Professor of Applied Mathematics 
Department of Mathematics

Robert T. Hanlon  
Assistant Professor and Station Director 
Department of Chemical Engineering

Richard K. Helling  
Department of Chemical Engineering

Nicole Herbots  
Department of Materials Science and Engineering

L. Gregor Herten  
Department of Physics

Ellen C. Hildreth  
Department of Brain and Cognitive Sciences

William O. Hubbard  
Department of Architecture

Mehran Kardar  
Department of Physics

Frank R. Karides  
Assistant Professor of Management 
Sloan School of Management

Don N. Kleinmuntz  
Assistant Professor of Management 
Sloan School of Management

Harri Kytomaa  
Department of Mechanical Engineering

Judith A. Lachman  
Assistant Professor of Management 
Sloan School of Management

Aneesh V. Manohar  
Department of Physics

Edwin Melendez  
Department of Urban Studies and Planning

Frank C. Miller  
Department of Architecture

Andreas Mortensen  
Department of Materials Science and Engineering

Ali Nadim  
Assistant Professor of Applied Mathematics 
Department of Mathematics

Terry Orr-Weaver  
Department of Biology

Leo Osgood  
Assistant Professor of Physical Education and Head Coach, Men's Basketball 
Athletic Department

Jason Phipps-Morgan  
Department of Earth, Atmospheric, and Planetary Sciences

Patricia C. Renaud  
Department of Mechanical Engineering

Daniel H. Rothman  
Department of Earth, Atmospheric, and Planetary Sciences

Michael F. Rubner  
Department of Materials Science and Engineering

Halston W. Taylor  
Assistant Professor in Physical Education and Head Coach, Men's Cross Country, and Assistant Coach, Track and Field 
Athletic Department
Robert J. Thomas  
Sloan School of Management

Er-Chang Tsai  
Assistant Professor of Applied Mathematics  
Department of Mathematics

Harry West  
Department of Mechanical Engineering

Jeffrey M. Wooldridge  
Department of Economics

Douglas C. Youvan  
Department of Applied Biological Sciences

Stephane T. Zaleski  
Assistant Professor of Applied Mathematics  
Department of Mathematics

Barton Zwiebach  
Department of Physics

Visiting Professor

Stephen L. I. Bacharach  
Department of Nuclear Engineering and Whitaker College of Health Sciences, Technology, and Management

Robert Beck  
Department of Ocean Engineering

Gottfied L. Boehm  
Department of Architecture

Michel P. Bouchon  
Department of Earth, Atmospheric, and Planetary Sciences

D. Keith Bowen  
Department of Materials Science and Engineering

Michael J. Buckingham  
Department of Ocean Engineering

Judith Chafee  
Department of Architecture

Peter P. S. Chen  
Department of Electrical Engineering and Computer Science

Robert C. Cummins  
Department of Linguistics and Philosophy

Jean-Loup Delcroix  
Department of Electrical Engineering and Computer Science

François P. Desseulx  
Department of Civil Engineering

Frank J. Fabbas  
Visiting Professor of Accounting  
Sloan School of Management

Colin R. Gardner  
Department of Applied Biological Sciences

Edward D. Hammond  
Director of the Army ROTC Program and Visiting Professor of Military Science

Donald W. Hearn  
Visiting Professor of Management Science  
Sloan School of Management

Alberto Holly  
Department of Economics

Robert J. House  
Visiting Professor of Organizational Studies  
Sloan School of Management

Jacob Katzenelson  
Visiting Professor of Computer Science and Engineering  
Department of Electrical Engineering and Computer Science

Conway Leovy  
Department of Earth, Atmospheric, and Planetary Sciences

Shlomo Maital  
Sloan School of Management

W. E. Lawrence Minter  
Crosby Visiting Professor of Earth, Atmospheric, and Planetary Sciences

James A. Mirrlees  
Department of Economics

Brian J. Mitchell  
Department of Earth, Atmospheric, and Planetary Sciences

Stephen Morgenstahler  
Statistics Center

William S. Mungall  
Department of Chemistry

Carlo Olmo  
Department of Architecture

Howard H. Patterson  
Department of Chemistry

John A. Pinto  
Department of Architecture

David C. S. Polk  
Department of Architecture

Yves Pomeau  
Visiting Professor of Applied Mathematics  
Department of Mathematics

Richard Pommer  
Department of Architecture

Scott F. Richard  
Visiting Professor of Finance  
Sloan School of Management

Erich Schneider-Wessling  
Department of Architecture

Michael Sela  
Department of Biology

Enid K. Sichel  
Department of Electrical Engineering and Computer Science

Anne O. Summers  
Department of Biology

Takahiko Tanahashi  
Department of Mechanical Engineering

Stavros B. Thomadakis  
Sloan School of Management

Howard Thomas  
Visiting Professor of Organizational Studies  
Sloan School of Management

Avraham Wachman  
Department of Architecture

Hugh R. Wilson  
Department of Brain and Cognitive Sciences

Visiting Associate Professor

Amr S. Azzouz  
Department of Civil Engineering
Julian Benjamin
Department of Civil Engineering

Avishai Ceder
Department of Civil Engineering

Shen Dong
Department of Mechanical Engineering

Albert T-K Hsui
Department of Earth, Atmospheric, and Planetary Sciences

Greta M. Ijung
Department of Mathematics

Marc A. Louargand
Department of Urban Studies and Planning

Michael J. Marcus
Department of Electrical Engineering and Computer Science

Jeffrey Mehlman
Visiting Associate Professor of French
Foreign Languages and Literatures Section

Kazuhiro Nagata
Department of Materials Science and Engineering

John M. Niedzwecki
Department of Civil Engineering

Paul Osterman
Sloan School of Management

Thomas A. Poynter
Sloan School of Management

Roger P. Simmonds
Department of Urban Studies and Planning

Jens C. Sorensen
Department of Ocean Engineering

Alexandra Sotiropoulou
Department of Mechanical Engineering

Laura Tyson
Department of Economics

Wen I. Wang
Department of Electrical Engineering and Computer Science

Russel S. Winer
Visiting Associate Professor of Marketing
Sloan School of Management

Visiting Assistant Professor

Ravindra K. Ahuja
Visiting Assistant Professor of Management Science
Sloan School of Management

Suzanne DeTrevile
Sloan School of Management

Denise DiPasquale
Department of Urban Studies and Planning

Ding-Zhu Du
Department of Mathematics

Zoltan Furedi
Visiting Assistant Professor of Applied Mathematics
Department of Mathematics

Peter J. Kemphorne
Visiting Assistant Professor of Management
Sloan School of Management

Charles Kolstad
Visiting Assistant Professor of Applied Economics
Sloan School of Management

Iris M. Mack
Visiting Assistant Professor of Applied Mathematics
Department of Mathematics

Henrique S. Malvar
Visiting Assistant Professor of Electrical Engineering
Department of Electrical Engineering and Computer Science

John Moore
Department of Economics

Yechiel Rosenfield
Department of Civil Engineering

Daniel H. Rothman
Department of Earth, Atmospheric, and Planetary Sciences

Rosemary L. Smith
Department of Electrical Engineering and Computer Science

Bert Spector
Sloan School of Management

Beverly A. Teicher
Department of Nuclear Engineering

Yoshiki Tsunekawa
Department of Materials Science and Engineering

Richard Wang
Sloan School of Management

AWARD

Mildred S. Dresselhaus
Institute Professor
Killian Award
Lecturer 1986-1987

ADMINISTRATION

DEATHS

Paul J. Gabriel
Department of Chemistry

Leo T. Green
Credit Union

RETIREMENTS

Virginia A. Bishop
Personnel Office

Dorothy L. Bowe
Student Financial Aid Office

Robert M. Byers, Sr.
Campus Information Services

Jacqueline Z. Colby
Libraries

Philip Cope
Office of Laboratory Supplies

Daniel H. Gould
Office of the Provost

Noelle B. Gove
Registrar's Office

Constance M. Holland
Faculty Club

Josef F. Jacquart
Administrative Systems

Dorothy R. Latsey
Resource Development Office

Nelson C. Lees
Resource Development Office

Samuel E. Leonard, Jr.
Food Services

Muriel J. Lewis
Libraries
Richard A. May  
Comptroller's Accounting Office  
Esther Merrill  
Sloan School of Management  
Patricia S. Moulton  
Office of Sponsored Programs  
August Perry  
Housing  
Robert R. Ragusa  
Comptroller's Accounting Office  
Harold W. Roberts  
Superintendent's Office  
Lawrence W. Ryan, Jr.  
Department of Chemistry  
Eleanor B. Smalley  
Office of the Bursar  
Nancy R. Urquhart  
Personnel Office  
Ruth E. Walsh  
Comptroller's Accounting Office  
Warren D. Wells  
Registrar's Office  

RESIGNATIONS  
Eric R. Albert  
Project Athena  
Jonathan D. Arnold  
Project Athena  
J. Peter Bartl  
Industrial Liaison Program  
Ornah R. Becker  
Personnel Office  
Russell Beharry  
Food Services  
Carmen N. Besterman  
Industrial Liaison Program  
Sarah E. Bingman  
School of Engineering  
Helen M. Blue  
Campus Information Services  
Pierre A. Boisaubin  
Administrative Systems  
Damon E. Bostick  
Information Services  
Paul R. Bragger  
Food Services  
David A. Bridgham  
Telecommunications Systems  
Sandra C. Buford  
Office of Sponsored Programs  
Patricia M. Catano  
Purchasing and Stores  
Kenneth J. Cerino  
Athletic Department  
Susan A. Chapdelaine  
Libraries  
Kenneth W. Chin  
Research Laboratory of Electronics  
Clara-Mae L. Chittum  
Libraries  
Thomas R. Courtney  
Project Athena  
James G. Cronburg  
Planning Office  
Virginia A. Cruz  
Safety Office  
Maureen C. DeCourcey  
Office of the Bursar  
Kenneth F. Deroeck  
Food Services  
Neil W. Didriksen  
Vice President, Resource Development  
John J. DiMiceli  
Information Services  
Kristin N. Djorup  
Libraries  
Judith M. Douglass  
Dean for Student Affairs  
Albert C. Epstein  
Food Services  
Eileen Wood Flugum  
Purchasing and Stores  
Elizabeth F. Fullon  
Alumni Association  
Elizabeth Gandolfo  
Food Services  
Julian W. Green  
Libraries  
Kathy Halbreich  
Committee on the Visual Arts  
Marilyn Ham  
Department of Applied Biological Sciences  
Evelynn M. Hammonds  
Project Athena  
Esther M. Hanig  
Child Care Office  
Susan E. Hardiman  
Food Services  
Victoria T. Harmon  
Audit Division  
Holliday C. Heine  
Dean for Student Affairs  
Norma E. Henderson  
Industrial Liaison Program  
Karen Hersey  
Office of Sponsored Programs  
Lois R. Hill  
Comptroller's Accounting Office  
Gisela R. Hoelzl  
Center for Real Estate Development  
Ellen N. Hoffman  
Communications/Resource Development  
Bertha Hoskins  
Project Athena  
Gregory B. Howland  
Treasurer's Office  
Barbara J. Hughes  
Information Services  
Lindsey V. Humes  
Development Office  
Micheline E. Jedrey  
Libraries  
Michael R. Jiencke  
Administrative Systems  
W. Scott Johnsen  
Industrial Liaison Program  
Anthony L. Jordan  
Planning Office  
Marie E. Kalenderian  
Administrative Systems
NEW APPOINTMENTS

Janet E. Abbate  
Systems Programmer  
Operations and Systems

Carl A. Accardo  
Industrial Liaison Officer  
Industrial Liaison Program

Mark S. Ackerman  
Applications Development Programmer  
Project Athena

NEW APPOINTMENTS
David Marsh
Industrial Liaison Officer
Industrial Liaison Program

Francis McCormick
Route Supervisor/Building Services
Physical Plant

Diane E. McLaughlin
Assistant Dean for Administration
School of Architecture and Planning

Michael J. McNamara
Purchasing Agent
Purchasing and Stores

Donna Mesthene
Staff Assistant, Equal Opportunities Office
Office of the President

Michael S. Mills
Assistant Manager, Maintenance, Housing and Food Services
Housing Office

Valderia A. Moore
Coordinator, Information Output
Alumni Association

Glenn H. Myers
Analyst Programmer
Comptroller's Accounting Office

Deborah D. Myrick
Facilities Coordinator
Operations and Systems

Brenda R. Nace
Personnel Administrator
Department of Physics

William Najjar
Subcontract Administrator
Purchasing and Stores

Steven T. Nalesnik
Assistant to the Director of Financial Aid for Systems Analysis Research
Student Financial Aid Office

Rose M. Needham
Night Supervisor
Superintendent's Office

Margaret Nelson
Assistant to the Bursar, Loan Collections
Office of the Bursar

Elizabeth A. Norton
Administrative Assistant, Planned Gifts and Legal Affairs
Treasurer's Office

Marie J. O'Connor
District Director
Resource Development

Cassandra N. Page
Campus Visits Coordinator
Resource Development

Paul S. Page
Manager of Systems
Purchasing and Stores

Ann Page
Personnel Administrator
Department of Earth, Atmospheric, and Planetary Sciences

Mark A. Palmgren
Program Officer, Council for the Arts
Office of the President

Elizabeth E. Pessek
Project Archivist
Libraries

Barbara A. Peterson
Student Programs Coordinator, Alumni Fund
Alumni Association

William J. Pierce
Preventive Maintenance Appraiser
Superintendent's Office

Amy L. Porter
Technology Licensing Officer
Technology Licensing Office

Susan Pritchard
Assistant to the Director of Safety Office

Harold E. Ramonat
Director of Major Gifts
Vice President, Resource Development

William H. Ramsey
Industrial Liaison Officer
Industrial Liaison Program

Charlotte G. Richie
Assistant Acquisition Editor
MIT Press

Victoria R. Risk
Assistant Manager, Microcomputer Center
Information Services

Rosanne Rizzi
Curatorial Assistant
Committee on the Visual Arts

Hannah D. Roberts
Administrator, Graduate Program
Department of Biology

Jon A. Rochlis
Assistant Network Manager
Telecommunications Systems

Clara I. Romero
Interior Designer
Physical Plant

Mark A. Rosenstein
Systems Programmer
Project Athena

Beth Ann Rosner
Circulation Manager, Technology Review
Alumni Association

Gitta B. Salomon
Consultant
Project Athena

Russell M. Sasnett
Applications Development Programmer
Project Athena

Stephen D. Scarano
Assistant to the Vice President, for Information Systems
Office of the Vice President

Bonnie Schaefer
Assistant Contract Administrator
Office of Sponsored Programs

Ronald S. Scharlack
Technology Licensing Officer
Technology Licensing Office

Marie E. Seamon
Assistant Coordinator, Conference Services
Campus Information Services

Chester T. Seymour
Auditor
Audit Division

Dorothy Shamonsky
Applications Development Programmer
Project Athena

Michael S. Shanzer
Systems Programmer
Project Athena
Margaret Shaw  
Analyst Programmer  
Administrative Systems

Ellen M. Sico  
Senior Staff Accountant  
Comptroller's Accounting Office

Kathy L. Simons  
Child Care Administrator  
Child Care Office

Judith Stein  
Administrative Assistant  
Sloan School of Management

Cynthia Stewart  
Assistant to the Director for Membership Activities  
Center for Real Estate Development

Diana Strange  
Associate Director, Alumni Fund  
Alumni Association

Maryann R. Taylor  
Development Officer for Major Gifts  
Vice President, Resource Development

James R. Tewhey  
Associate Dean and Section Head, Residence and Campus Activities  
Dean for Student Affairs

Scott E. Thorne  
Analyst Programmer  
Administrative Systems

Kiet Van Tran  
Production Analyst  
Operations and Systems

G. Winfield Treese  
Systems Programmer  
Project Athena

Maria L. Vieira  
Assistant to the Director of Education  
Center for Real Estate Development

Lisa Walker  
Analyst Programmer  
Comptroller's Accounting Office

Kimball C. Warren  
Consultant  
Information Services

Roger H. Watkins  
Assistant Director  
Student Financial Aid Office

David A. Weber  
Associate Director of the Master's Program  
Sloan School of Management

Kenneth R. Weakes  
Assistant to the Bursar, Loan Collections  
Office of the Bursar

Arnold N. Weinberg  
Medical Director and Head, MIT Medical Department  
Office of the Vice President

Federico Welsch  
Research Development Officer  
Harvard-MIT Division of Health Sciences and Technology

Julia A. Werbinski  
Assistant Auditor  
Audit Division

Carl P. Whitaker  
Supervisor, Benefits Systems and Records  
Personnel Office

Barbara Whitesides  
Associate Director for Programs and Publications  
Center for Real Estate Development

Phillip G. Wickens  
Manager Dietary Service  
Medical Department

Varian F. Woolfork  
Supervisor, Registration Registrar's Office

Susan Wu  
Staff Accountant  
Comptroller's Accounting Office

Ellen Ying Yen  
Librarian  
Libraries

Stephen H. Young  
Supervisor, Mechanical Services  
Physical Plant

Helene R. Zatloff  
Assistant to the Bursar  
Control and Accounting Office of the Bursar

Carol A. Zoppel  
Librarian  
Libraries

CHANGES

Sarah Abrams  
Staff Writer/Editor  
Communications/Resource Development

Richard A. Ackerson  
Maintenance Supervisor  
Superintendent's Office

Mary C. Albano  
Senior Database Analyst  
Administrative Systems Development

Katherine K. Allen  
Administrative Assistant to the Vice President for Information Systems  
Vice President for Information Systems

Guillermo E. Alvarez-Vega  
Analyst Programmer  
Comptroller's Accounting Office

Arthur L. Anger  
Senior Consultant  
Information Services

Anne E. Armitage  
Program Administrator  
Integrated Studies Program School of Humanities and Social Science

John G. Arrison  
Curator, Hart Nautical Collections  
Libraries

Gregory Arsenault  
Analyst Programmer  
Fiscal Planning and Budget Office

Paul J. Arsenault  
Accounting Officer  
Comptroller's Accounting Office

Roderick R. Arthur  
Assistant Director of Athletics for Faculty Scheduling, Operations, and Maintenance  
Athletic Department
Judith M. Douglas  
Assistant Dean for Student Affairs  
Dean for Student Affairs

Barbara A. Durland  
Assistant to the Vice President, for Information Systems  
Vice President, Resource Development

Diane J. Eisenhaur  
Contract Administrator  
Office of Sponsored Programs

Andrew M. Eisenmann  
Senior Staff Associate, Residence and Campus Activities  
Dean for Student Affairs

Mary Z. Enterline  
Assistant Dean, Undergraduate Academic Support  
Dean For Student Affairs

Maryrose Framo  
Assistant to the Director for Administration  
Admissions Office

Deborah L. Fairchild  
Senior Budget Officer  
Fiscal Planning and Budget Office

Rhoda Fischer  
Writer/Editor  
History Section

David T. Flett  
Manager, Campus Activities Complex  
Superintendent's Office

Michael W. Foley  
Manager, Campus Activities Complex  
Superintendent's Office

Dana Friis-Hansen  
Assistant Curator, List Visual Arts Center  
Committee on the Visual Arts

Lawrence D. Gallagher  
Manager, Video Services  
Graphic Arts

Phyllis M. Gallant  
Assistant to the Director of Development Services  
Development Office

Mary E. Gibson  
Budget Officer  
Fiscal Planning and Budget Office

Norma M. Gicka  
Fiscal Manager  
Sloan School of Management

Joseph F. Gifun  
Manager of Building Maintenance  
Superintendent's Office

Yvonne L. Gittens  
Associate Director  
Student Financial Aid Office

Anne P. Glavin  
Captain  
Campus Police

Luz M. Gordillo  
Analyst Programmer  
Administrative Systems Development

Eduardo Grado  
Coordinator of Minority Admission and Assistant Director of Admissions  
Admissions Office

Frederick P. Gross  
Director of Corporate Development  
Vice President, Resource Development

Margaret Gutowski  
Assistant Director, Major Gifts  
Vice President, Resource Development

Elizabeth T. Harding  
Director of Communications  
Vice President, Resource Development

Alan E. Harrington  
Accounting Officer  
Comptroller's Accounting Office

Donald E. Heller  
Assistant to the Vice President, for Information Systems  
Office of the Senior Vice President

Candace K. Hopkins  
Analyst Programmer  
Alumni Association

William F. Hogue  
Assistant Director  
Project Athena

Paul J. Honiker  
Personnel Administrator  
Comptroller's Accounting Office

Barbara Jo Hughes  
Senior Consultant  
Information Services

Elizabeth C. Hurlbert  
Security Records Supervisor  
Office of Sponsored Programs

Jules M. Hurwitz  
Consultant  
Information Services

John J. Hynes  
Coordinator  
Office of Sponsored Programs

Yasuyo Iguchi  
Designer  
MIT Press

C. Nicholas James  
Manager, Animal Facilities  
Division of Comparative Medicine

Anastasia J. Janus  
Senior Staff Accountant  
Comptroller's Accounting Office

Bonnie S. Jones  
Program Manager, Student and International Programs  
Alumni Association

Estil Jones  
Assistant Manager, Campus Activities Complex  
Superintendent's Office

Marc B. Jones  
Administrative Officer  
Department of Chemistry

Michael J. Karaffa  
Manager, Physical Plant Operations, LINAC  
Physical Plant

Demetri A. Karageorge  
Assistant Accounting Officer  
Comptroller's Accounting Office

Robert K. Kaynor  
Associate Director of Planning  
Planning Office
This is my second year as Provost and I would like to make a few observations about what I believe are the accomplishments of my second year in office and, more importantly, the major challenges in the year ahead.

Before proceeding, I wish to express my appreciation to Abraham J. Siegel who will be stepping down as Dean of the Sloan School of Management. Abe has made important contributions to the Institute and his leadership of the Sloan School has been central to the School's impressive success. I am personally grateful to him. I look forward to working with his successor, Lester Thurow in continuing the successful record of the School.

The accomplishments of the year which I view as most noteworthy follow.

1. Considerable progress has been made in a number of aspects of undergraduate education and undergraduate life at MIT.

   The Office of the Dean for Undergraduate Education has undertaken several new initiatives including (a) strengthening the freshman advising, freshman seminar program, (b) undertaking an important review of the housemaster system, and (c) continuing to address the problems—and opportunities—for underrepresented minority students at MIT.

   The Dean for Undergraduate Education has worked with the many groups in the various schools in formulating proposals for change in the undergraduate curriculum. At the end of the year, the faculty voted two important changes in the curriculum: (a) establishing an option for an undergraduate minor in humanities, social science and the arts, and (b) modifying the undergraduate humanities distribution requirement. I anticipate further important proposals for academic reforms in the coming year.

2. The five-year planning process continues, in my judgement, to be an important tool in managing resource allocation. It is an effective vehicle for establishing a baseline for where we are going and what we believe to be of greatest importance to education and research excellence in the future. This year the focus in the planning process was on support areas of the Institute. I was impressed by the attention these elements of MIT devote to serving the Institute efficiently and I believe the process of review was beneficial to these important elements of the Institute community.

3. The subcommittee of Academic Council has made significant progress in setting priorities for the upcoming MIT Campaign for the future. The group has also begun the necessary process of organizing the faculty and staff for support of our resource development efforts.

4. The process of governance of the Lincoln Laboratory has been strengthened in a number of ways. An external advisory board has been established and in its several meetings, this board has demonstrated the important contributions it can make to Lincoln Laboratory's vitality. The standing Faculty Committee at Lincoln Laboratory has been given a new charter in response to the Committee report of the prior year and I am optimistic that this Committee's work will strengthen ties between the campus and the Laboratory. It also appears that Lincoln will be authorized to construct a new building in the coming year which will provide the Laboratory with the modern laboratory facilities it deserves.

5. A number of programmatic initiatives have been successfully launched. These include:

   The establishment of a Faculty Committee to Review the Arts at MIT under the chairmanship of Professor Paul Joskow. This Committee is charged with reviewing the strengths and aspirations of the MIT community in the visual and performing arts and to make recommendations about steps which should be taken to expand our activities in these important areas. Recommendations have been received and acted upon for drama and dance and I expect that further action will be taken shortly with respect to the visual arts.

   The Center for International Studies has been given new resources and Professor Myron Wiener has succeeded Professor Eugene Skolnikoff as director. In addition, a review group has been established and external funding efforts initiated to provide stable, long-term support to the arms control program.
It has proven possible to continue our efforts to reduce our dependence on federal grants for academic year salary support, especially in the School of Science. This initiative not only makes us more competitive in seeking federal research support, it also contributes importantly to reducing the pressure of individual faculty to raise money. The expenses of this effort means that it will take several years to accomplish our objective of substantial reduction in our dependence on research sponsors for academic year salary recovery.

The MIT Commission on Industrial Productivity has been established under the chairmanship of Professor Michael Dertouzos. This group of faculty is studying the causes of the productivity problems of this nation and intends to make recommendations about how these problems might be solved and what MIT should do in its education and research programs to assist the nation in dealing with this critical subject.

As I mentioned last year, much remains to be done. I said then and repeat again, "Perhaps the most important requirement is to maintain an atmosphere at the Institute that encourages excellence and innovation in our scholarly activities, especially for students and younger faculty, and maintains an air of excitement. The critical factor for establishing this atmosphere is the availability of adequate resources to support the many, worthwhile, new educational and research initiatives, which are proposed by the faculty and other members of the Institute community. The key for achieving adequate resources is the success of the upcoming Campaign at MIT. Accordingly, the single most important item on my agenda for the upcoming year is to mobilize the Institute community for the Campaign."

We are much better deployed to achieve this result. All the Schools now have able resource development individuals who are dedicated to the success of our fundraising efforts. During the coming year, I expect with the launching of the Campaign, to see concrete results. I hope we should be able to begin the science complex project which will provide for a much needed new biology building, a centrally located renovated center for the Physics Department, and release of space currently occupied by the School of Science which will be available for use by the School of Engineering.

There are many other subjects on the agenda of the Office of the Provost for the coming year. A few of these are:

- Improving the Institute's performance in hiring qualified women and underrepresented minorities, especially for the faculty. I continue to believe that successful affirmative action is important for MIT and, indeed, for all leading universities in the nation.

- Understanding the consequences of the federally mandated lifting of the mandatory retirement age in 1991 for the tenured faculty of MIT and for the higher education system generally.

- Dealing with the difficult issue of faculty salary increases. In recent years we have generally met, but not led, the academic market for faculty salaries in each discipline and this has led to a welcome improvement in the real income of the faculty. But at a time when inflation has abated and our sources of income, especially tuition, are not increasing as rapidly as faculty salaries, we run the risk of creating a financially untenable situation. Something must be done. There is particular concern about the effect on our ability to attract new faculty because of the high real estate market in the Boston area and we plan to add further assistance programs to alleviate this problem.

It will not be possible to make significant progress on these and other issues without the support of the faculty and staff. I trust that this support will be as forthcoming during the coming year as it was during the past year.

JOHN M. DEUTCH
Libraries

There is a temptation when recording the progress of an organization like the MIT Libraries to focus on major events and crises and, possibly then, fail to recognize the general effectiveness of the institution in maintaining the set of activities for which it is principally responsible. During the year recently ended, the Libraries faced a number of challenges and critical situations involving, among other issues, automation, the acquisitions budget, staffing in the Engineering and Science Libraries, and the closing of two public service units. Staff in most areas were hard pressed to fulfill their usual responsibilities in addition to working on special projects and tasks and, often, carrying an extra set of duties. The accomplishments of the MIT Libraries in 1986/87 were essentially the accomplishments of the entire staff -- librarians, specialists, support staff, and students -- in a collective effort that produced exceptional results. What should not be overlooked in particular is that the primary and basic activities of the Libraries -- selection, acquisition, cataloguing, reference and information, administration, planning, exhibitions, and service -- continued unabated despite the pressures. In a sense, the most exceptional thing about the past year is that it was unexceptional in terms of basic operations. Full credit for this belongs to the staff of the MIT Libraries.

Automation

During the past year the Libraries accelerated its transition from a manual to an online environment. The goals outlined in the previous annual report have almost all been reached. A few will be attained during the coming months. The MIT Libraries is now in the process of securing the resources necessary for the expansion of the online system, Barton, to a larger and more sophisticated version of Geac, the 9000; implementation of the new hardware and software is anticipated during the summer of 1988.

The principal advances in the systems area include the installation of the first public Barton terminals, providing online access to the Libraries' bibliographic database of over 350,000 records. These were received with great enthusiasm by students and faculty as might well have been expected; the placement of additional terminals is continuing with considerable impetus since the availability of sufficient public access terminals is critical to the closing of the catalogue as outlined below. In addition, the Libraries will be beginning to provide dial-up access for MIT laboratories and research centers within the next calendar year.

Another significant accomplishment was the creation of a serials database of over 25,000 records in collaboration with the Faxon Company. The Systems Office worked closely with the Serials Cataloguing staff and with Geac, to coordinate the matching of Faxon and OCLC records. Also developed was an algorithm for special processing of Faxon records to permit the splitting of author and title entries. The close cooperation of Faxon, Geac, and the MIT Libraries was a singularly impressive and highly rewarding project. The serials database is now available to the public via the online catalogue.

Among the other systems-related activities was the final acceptance test of the Geac system and payment of the final installment on the original contract. Online circulation became operational in all library units; the reserves module was tested during the spring semester in the Reserve Book Room; specifications for and a sample of a tape interface with the Bursar's Office were produced; MIT served as a Beta test site for an upgrade in the Marc Record Management System (MRMS) including a major change in the security/access module; a test tape for a COM fiche version of the database was produced.

Closing the Catalogues

While the implementation of an expanded online catalogue with online authority control and Boolean search strategy must await the installation of the Geac 9000, plans continued during the year for the closing of the card catalogues. The basic plan is to discontinue the filing of cards and the maintenance of existing records in all catalogues within the 1987 calendar year. The conclusion of this plan depends on a number of factors: the installation of a sufficient number of public access terminals; the implementation of the input of on-order records into the online catalogue; the design of a plan for the removal of cards for records already online and the consolidation of the remaining records; the creation of a back-up version of the online catalogue on a continuing basis using either COM fiche or CD-ROM technology; and a long range plan for retrospective conversion of remaining items. Two concurrent efforts were begun that were designed to effect the smooth transition to an online environment. The Systems Librarian and the Associate Head of the Catalogue Department for Online Operations were asked to coordinate the closing of the card catalogues and implementation of the online replacement. The Head of the LC Cataloguing Section was asked to chair a Catalogue Department Committee on the Transition to the Online Catalogue. By the end of the academic year, this Committee had made and the administration had approved a number of recommendations. The recommendations included no longer filing subject cards in the Institute Library Catalogue and branch library catalogues; the discontinuing of typing authority
records that duplicate Library of Congress authority records; the end of recording item level holdings in the union shelflist and branch library shelflists; and the acceptance of Library of Congress practice for the tracing of series except in unusual cases.

Serial Prices

Along with every other research library and many college and small university libraries, the MIT Libraries suffered an extraordinary decrease in purchasing power through a combination of unprecedented price increases and the decline in the value of the dollar abroad. At mid-year it was estimated that the shortfall in the serials budget for the ensuing 12 to 18 months would be in the region of $250,000. While the Institute administration was able to assist with an addition to the budget, the serial prices crisis required the cancellation of a large number of titles, many of them unique. While there is cold comfort in the knowledge that MIT does not stand alone in this situation, it is especially difficult here because of the great dependence in engineering and science on serial publications. Overall, 75% of the Libraries’ acquisitions budget is used to acquire serial publications.

Little can be done by research libraries in reversing the decline in the value of the dollar. It is unfortunate for MIT that the dollar has done particularly poorly in countries where a large number of scholarly journals of interest are published: West Germany, the Netherlands, Japan. It is less evident, however, that action can not be forthcoming with regard to unwarranted price increases instituted both by commercial publishers and learned societies. Some have argued that these increases are justified because of an increase in the number of issues and/or the number of pages. Other reasons include the cost of materials and labor; printers’ strikes; and the cancellation of individual subscriptions. In at least one case, a publisher of scientific and technical periodicals has openly stated that libraries seem to continue to subscribe regardless of price. This latter attitude appears to be unduly optimistic! It is becoming increasingly clear that research libraries have reached the bottom of their institutional pockets with regard to serial acquisitions funds. It is certainly becoming more evident that university administrations are neither able nor willing to fund inflationary increases in serials budgets that are double or triple the Consumer Price Index. Libraries will be cancelling subscriptions. Since these libraries have long ago cancelled most of their duplicate subscriptions, they will cancel unique titles. Some of these titles will be important to research and teaching programs. Some will be journals in which local faculty publish and on whose boards of editors they serve. Some libraries will work collectively to try and reduce the impact of cancellations. The situation has reached the point where it is no longer important why prices are increasing at a horrendous rate. The simple fact is that there are no more sources for additional funds. Research librarians, publishers, and faculty members will have to stop blaming each other for the situation and begin to work more effectively together. Publish or perish may well be critical in faculty promotion and tenure decisions; cancel or perish has become the result for the research library.

Organization and Personnel

Two library public service units were phased out during the past year. In response to concerns expressed for quite some time and particularly during the last few years by the Department of Chemistry with regard to extended access to the chemistry collections in the Science Library, the Libraries proposed and the Department, agreed to close the Chemistry Reading Room in exchange for extended hours in the Science Library. Subsequently and somewhat related, it was proposed to the Dean for Student Affairs that the Student Center Library be converted from a 24 hour library/reading facility to a study facility only and that, further, it be administered by the Dean’s Office. This library had, over the past few years, become less and less a library with the elimination of duplicate reserve collections (due to budgetary constraints) and the installation of a Project Athena cluster. By the end of the academic year, arrangements had been completed for the transfer of responsibility and some funds to the Dean for Student Affairs. Some of the funds released through this second closing were added to the Chemistry Reading Room budget with the result that as of June, 1987, the Science Library (and Humanities Library, since it shares a single control point) are being kept open 24 hours a day, year round. From midnight until 8 a.m., (from 8 p.m. on Friday and Saturday and from noon on Sundays) access is limited to members of the MIT community. While neither reference nor circulation services are available, access to the collections and to copy facilities has already generated considerable use that is expected to grow as the availability of this facility becomes better known.

The past year also saw a major administrative reorganization of the Engineering and Sciences Libraries. The coincidental vacancies of Head, Engineering Libraries and Head, Science Libraries prompted a major review of the staffing of these key public service units. The restructuring created four positions that provide a single administration for the two previously separately administered libraries. The senior administrator, Head, Engineering and Science Libraries, will be assisted by three Associate Heads -- for collection management, for access services, and for information services -- who will serve both the Engineering and Science Libraries. It is expected that this reorganization will result in a more coordinated program of collection management and information services as well as in better utilization of personnel. The benefit to individual staff members who will work in both libraries is also potentially significant.

Several other administrative changes were implemented at the end of the year. The position of Systems Librarian was upgraded and the incumbent promoted to the position of Associate Director for Systems and Planning. The Preservation and Collections Librarian was made a department head and a member of Library Council. That position now includes responsibility for the Binding and Repair Unit, for the RetroSpective Collection, and for
The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

Gifts

The flow of donated material continued during the year with a number of large collections of books and papers as well as several extremely valuable items. Collections were received from Sidney Alexander (economics), the Cabot Corporation (aerial photographs), Ira Dyer (naval architecture and marine engineering), Gary Hack (urban studies and planning), Morris Halle (linguistics and Russian literature), the Kanazawa Institute of Technology (Japanese architecture), Carl Kayser (economics and higher education), Kevin Lynch (urban studies and planning), Gary Marx (urban studies and planning), Walle Nauta (medical periodicals), T.S. Ramakrishnan (business), Gian-Carlo Rota (mathematics, philosophy, and literature), the State Education Commission of the People's Republic of China (humanities and social science), and Richard Wurtman (medical periodicals). Three specific items of note were the gift of the first edition of Descartes' *Discours de la methode* (1637) from John D. Stanitz of the Class of 1942; Stokes' *Iconography of Manhattan Island* (1915-28) given by Alan Rabinowitz; and the 19th century American classic, *Dictionary of Architecture*, the purchase of which was funded by I. Austin Kelly, III, of the Class of 1942; and Herbert Scoville, arms control and disarmament services committee.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.

The MIT Libraries did receive funding from the U.S. Office of Education under its Title II-C program for a second year of retrospective conversion of MIT technical reports and other research publications. That project will be completed in December, 1987.
Important additions to the MIT Museum's collections included the LJ magnet from the National Magnet Laboratory; the Alcator A from the Plasma Fusion Center; and two nucleic acid models from the Department of Biology. Other significant acquisitions were an oil painting and two preliminary studies by Charles H. Woodbury along with two original sketches of the Edwin Blashfield murals in Morss Hall. The Hart Nautical Collections received a further installment of ship plans from the Bethlehem Quinnc Shipyard archive.

A new endowed book fund was established in memory of Harold R. Isaacs, Professor of Political Science. Several additional endowed funds, one of them in music, were in the process of development by the end of the academic year.

MIT Museum and Historical Collections

One of most significant exhibits in the Museum's history and a major cultural event for the greater Boston area was the Bauhaus exhibit and accompanying programs. It involved a great deal of effort on the part of the entire Museum staff and required close coordination with 14 other Boston area institutions. For the first time nearly all Museum space in the central facility was devoted to a single theme. Attendance throughout the exhibit was extremely high and the Bauhaus displays attracted many people who had never visited the Museum before. There were numerous reviews in a variety of newspapers and magazines, all of which were quite laudatory.

The Museum Shop continued to increase in activity with sales up almost 80% over the previous year. With funding from the Raytheon Company, the Museum produced an educational videotape that documented the history and development of the subminiature vacuum tube, a prime element in early hearing aids, the World War II proximity fuse, walkie-talkies, and encrypting devices. The actual manufacturing processes were filmed at the Raytheon plant in Quincy just before that facility closed. Copies of the tape are being offered to museums and other interested institutions without charge and some 70 copies have been distributed to date. A proposal to produce a similar tape documenting the development of radar at the MIT Radiation Laboratory is being prepared.

The Museum continued to sponsor a number of films, lectures, workshops and seminars on a variety of topics. In addition, there were a number of other exhibits in Compton Gallery, at the central facility, and in the Hart Nautical Galleries. Among the artists/topics were Gyorgy Kepes, dye transfer photographs, anti-nuclear war posters, digital photography, Donald Stoltenberg, ship half-models, architect Benjamin Thomson, computer art, hand bound books, Martin Mugar, microphotographs, holoigraphy, and Werner Graeff.

Institute Archives and Special Collections

A vacancy in the position of Records Manager prompted a study of the organization of the Institute Archives and resulted in the designation of the Assistant Archivist as Associate Archivist and Records Management Officer. This change will insure a greater coordination of activities between archives and records management. In addition, a new position of Assistant Archivist was created. The second year, actually only a half year, of the Title II-C grant resulted in the completion of processing of nine collections with a total volume of 253 cubic feet. The major collections processed under the grant included the Mid-Ocean Dynamics Experiment, Dynamic Analysis and Control Laboratory, Energy Laboratory, National Magnet Laboratory, Neurosciences Research Program, Servomechanisms Laboratory, Wright Brothers Wind Tunnel, Northeast Radio Observatory Corporation, and the papers of William Seifert. Work continued on the project sponsored by the Andrew W. Mellon Foundation that is aimed at producing an appraisal strategy for college and university archives. A singular effort in the Records Management Program resulted in the publication of the first major guide to MIT official records: Guide to the Retention of MIT's Financial Records.

A Selection of Important Items

To return to a theme outlined earlier: a great deal of what happens in a research library is a continuation of what has gone before. The annual reports of the several departments and specialized units that comprise the MIT Libraries are full of significance and chronicle the efforts of a large number of individuals. Space does not permit a detailed description of these items but the following should provide a sense of what goes on in a major academic library.

- The Acquisitions Department made significant inroads into the backlog of MIT reports transferred from the Industrial Liaison Program.
- The Catalogue Department maintained a steady flow of MIT thesis cataloguing, reaching a point of stasis where there is essentially no backlog in this area.
- The replacement of old Xerox copiers by newer Oce copiers with magnetic card charging has produced a great improvement in the quality of quick photocopying. The Microreproduction Laboratory, through this innovation, has made one of the most significant changes in a major service
area in the recent history of the Libraries. The reaction of users has been universally favorable. The installation of an oversize copier in Rotch Library has also met with a positive reaction.

- The Libraries' delivery unit, under the supervision of Administrative Services, maintained an efficient and timely service despite an increase in volume of activity and the addition of a twice-weekly trip to the Boston Public Library for Boston Library Consortium mail.

- Dewey Library staff participated in 13 separate instructional sessions involving 308 individuals. A similar level of activity may be found in the reports of the Science, Rotch, Engineering, and Humanities Libraries.

- The Barker Engineering Library served successfully as a test site for a fee-based online reference service for non-MIT patrons. (The entire question of fee-based services for external users is currently under study by a staff committee.)

- The Aeronautics and Astronautics Library installed a security system; this is the second such improvement among the Libraries' branch libraries.

- The Humanities and Science Libraries planned and executed a major shift of the Hayden Library collections, providing much better access and space for expansion.

- In Rotch Library, a major effort was undertaken to develop a program of services for the new Center for Real Estate Development. The staff continued to cope with a major space problem in a library that suffers from a lack of air conditioning and humidity control. Rotch Visual Collections, however, was finally air conditioned.

- The Science Library maintained a high level of service despite staff shortages and a major disruption caused by the installation of new carpeting.

- The Computerized Literature Search Service showed an overall increase in the volume of activity with no additional staff. CLSS ran a seminar for Industrial Liaison Program staff.

- Work was completed to improve air circulation in Hayden Library's basement thus providing much better environmental conditions for the Binding Unit staff and for rare books; the public should, as well, notice a major change for the better.

- The RetroSpective Collection received and shelved without any disruption of service, the complete collection of materials previously stored in the New England Deposit Library.

- All committees of the Libraries continued to function smoothly. The Staff Development Committee sponsored a number of programs. The Collection Management Group undertook an evaluation of the New Title Announcement Service, completed its study of government documents, and did a major revision of the "T" conspectus. The latter was undertaken at the request of the Research Libraries Group. The Circulation Committee coordinated the successful implementation of the Barton Circulation module and the testing of the reserve module.

- During the Independent Activities Period in January, 1987, the staff sponsored a number of programs, many of them repeats of successes of previous years. A contest to produce a set of photographs emblematic of the MIT Libraries turned out to be an immense success.

- A proposal submitted jointly by the Libraries and the Graduate School of Library and Information Science at Simmons College to the Council on Library Resources was funded. The project is intended to produce a better interface between the Libraries' online information system and its users.

- MIT joined with 57 other research library members of OCLC to inaugurate a faculty reciprocal access program.

A Tribute

Five long term members of the staff left during the past year. Two senior staff of the Catalogue Department, Jacqueline Z. Colby and Muriel Lewis retired. Both have had distinguished careers at MIT and contributed measurably to the development and progress of this most important element in the organization. Kate Herzog, who served for many years in the Engineering Libraries, most recently as Associate Head and Acting Head, departed to become Engineering Librarian at UCLA. Kate was deeply involved in the activities of the MIT Libraries in all aspects of public service and, in recent years, in collection management. Micheline Jedrey, Associate Librarian of the Rotch Library of Architecture and Planning and, at one time, Acting Rotch Librarian, was appointed Associate Director for Technical Services at Wellesley College Library. Micheline had a major role in the implementation of the online system including serving as chair of the Bibliographic Study Team.
Susan K. Nutter, Associate Director for Collection Management and Technical Services, was appointed Director of Libraries at North Carolina State University, Raleigh. Her ascension to the ranks of ARL directors is a noteworthy event recognizing her stature in research librarianship and her achievements in collection management and technical services. A member of the staff for 21 years, Susan Nutter will leave a gap that will not be easily filled. Her contributions to the Libraries and the Institute will serve, however, as a lasting reminder of her presence on the staff.

Epilogue

An annual report such as this one is intended to highlight the events of the previous year. It should also be viewed as a record of the overall accomplishments of an institution. In reality, however, the year never ends. The work of the MIT Libraries is a continuum -- staff, collections, services -- aimed at providing a ready response to the intellectual needs of the MIT community and anticipating the requirements of future scholars and students. Major emphasis in the coming year will be on extension of the online system; expansion of Rotch Library; development of a planning process; and a whole range of other exciting and challenging issues. The year will also see a continued emphasis on maintaining a well organized set of collections with responsive services and careful management of resources. Maintaining a balance between these two competing sets of efforts serves to keep the staff and the administration of the Libraries on their collective toes.

JAY K. LUCKER
Lincoln Laboratory is operated by MIT as a Federal Contract Research Center for performing research and development in advanced electronics. During the past year, agencies of the Department of Defense (DoD) -- the Air Force, Army, Navy, and the Defense Advanced Research Projects Agency (DARPA) -- supplied 95 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1986 the operating budget was $343 million, supporting the efforts of 846 professional staff, 81 percent of whom hold advanced degrees.

Several administrative changes at the Laboratory Steering Committee level occurred during the year. Jerome Freedman retired as Assistant Director and was succeeded by William P. Delaney, until then Head of the Surveillance and Control Division. Carl E. Nielsen, Jr., became Head, and Dr. David L. Briggs and John C. Fielding became Associate Heads of that Division. Dr. Melvin A. Herlin retired as Assistant to the Director and was succeeded by Alan A. Grometstein.

Technical work areas at the Laboratory include radar and optical sensors, measurements, and systems; satellite communications; signal design and processing; lasers; solid-state devices; digital technology, circuitry and data systems; tactical and strategic systems and countermeasures; and air traffic control systems. Unclassified highlights of several accomplishments during the past year are summarized below.

AIRBORNE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new systems for air traffic control. Principal emphasis has been on systems for aircraft and weather surveillance, collision avoidance, and ground-air-ground data-link communications.

As an outgrowth of work done by the Laboratory in radar beacon surveillance systems, a program to develop an airborne traffic alert and collision avoidance system (TCAS) began in 1975. Lincoln Laboratory has been responsible for the design of the beacon-based, air-air surveillance function of TCAS, with emphasis on the capability to operate in dense airspace. The TCAS unit tracks all nearby, beacon-equipped aircraft and provides the pilot with the locations of other aircraft and, when necessary, advice on collision avoidance maneuvers. The Laboratory has conducted extensive tests of the experimental equipment and has worked closely with the FAA and industry to accomplish a successful technology transfer. Operational evaluations of TCAS are scheduled to start in 1987 in four U.S. airlines, and one of these currently is underway. Following certification by the FAA, TCAS is expected to be required in all U.S. air carriers.

Until recently, TCAS has been tested only on fixed-wing aircraft. However, there has been a long-standing interest in collision avoidance protec-
tion for helicopters. A helicopter environment presents a different set of technical problems from fixed-wing aircraft due to the limited locations for antennas, the relatively complex structure which affects the antenna radiation patterns, and the different dynamic conditions induced by the high turning rates of helicopters. The Laboratory recently completed a series of flight tests with a TCAS unit mounted in a civil helicopter. Very few modifications were made to the original fixed-wing design, and the system performed well. At the end of the evaluation, professional helicopter pilots were invited to fly the TCAS-equipped helicopter and their reactions were positive.

The Laboratory will continue to be involved with the TCAS system as operational tests proceed and future improvements evolve.

OPTICAL AIRCRAFT MEASUREMENT PROGRAM

Increasing emphasis is being placed on ballistic missile defense constructs which require multiple-band infrared data to identify re-entry vehicles among debris and decoys. There is an urgent need for data of this type on existing missile re-entry systems to develop and validate optical discrimination algorithms. Since late 1982, the Laboratory, under Army sponsorship, has directed the design and development of a large airborne infrared measurement system. The Optical Aircraft Measurement Program (OAMP) sensor consists of an optical subsystem, an infrared focal plane, signal processing equipment, and a platform stabilization and pointing system. The sensor is installed in a specially designed compartment and carried by a converted RC-135 aircraft.

The totally reflective optical subsystem is designed to collect and focus radiation from exoatmospheric objects onto the infrared focal plane. The detectors in the focal plane, cooled to 15 K, are close to the theoretical background noise limit. Two modes of operation are supported by the focal plane: scanning of many objects using a large linear array operating in one spectral band, and tracking of a single object using three smaller spectral bands. The real-time signal processing resource aboard the aircraft is used to optimize detection and generate object position estimates for the servo system. During tracking the line of sight is stabilized by a gimbal servo system complemented by a wide-bandwidth, cryogenically cooled, two-axis steering mirror.

During the past year the major subsystems were assembled and tested in anticipation of final integration aboard the aircraft. Every test result indicates that the high precision required of the instrument will be realized. Test flights of the instrument are scheduled for August 1987.

The OAMP sensor was designed to allow new focal planes to be easily installed as the technology becomes available. The natural upgrade paths currently being pursued include new focal plane designs and track-while-scan capability.
NEURAL NETWORKS

Applications of neural networks are being pursued in the domains of speech recognition, object recognition from imagery data, and complex decision problems. In addition, several approaches to implementing neural networks in silicon are being investigated.

In the area of speech recognition, a new neural network design, which implements a Viterbi search algorithm, has been developed and is currently being evaluated for implementing the word recognition function as part of a hidden Markov model-based continuous speech recognition system. The pattern classification power of multilayer neural networks is being investigated for implementing Gaussian and K-nearest neighbor classifiers, both of which find use in word or speech recognition applications. Kohonen's self-organizing feature maps are being used to build a vector quantizer from training data, and the Tank/Hopfield time concentrator model is being applied to the problem of temporal pattern recognition as an alternative word recognition scheme.

In the area of object recognition, a theoretical linkage between neural networks and statistical estimation theory has been found. Characterizing the regions of an image as sample functions of a Markov random field leads to an optimum processor for segmenting the image, which can be realized as a neural network. This result affirms that the style of information processing performed by neural networks does have a solid theoretical basis for certain cases. Also, a number of neural network architectures developed in the context of cognitive modeling are being applied to various aspects of the object recognition problem. In particular, a neural network implementing the cognitive models of Grossberg and Mingola is being applied to the problem of image segmentation. This effort involves simulating a multilayer network characterized by many thousands of partial differential equations. The larger goal of this work is to develop a multilayer neural network processing system for target recognition, based on multidimensional imagery produced by a variety of sensors, such as a laser radar.

SIGNAL PROCESSING APPLICATIONS OF RESTRUCTURABLE WAFER-SCALE TECHNOLOGY

A new laser link structure, developed to expedite the building of wafer-scale circuits in industry and which can be fabricated in any standard MOS fabrication line without additional process steps, has been used to build a dynamic time warping (DTW) system for speech recognition. To demonstrate the transferability of this process, DTW wafers were fabricated in the MOSIS silicon foundry (3 μm bulk CMOS, 3" wafers) and restructured using the laser facility at Lincoln. The wafer, comprising about 300,000 working transistors, has recently been installed in a real-time speech recognition system.

A second wafer, a flexible multiply-accumulator array which uses the earlier vertical, amorphous silicon link, was restructured to implement the Hough Transform, a signal processing function which fits straight line segments to clusters of data points. This circuit is now functional in a laser radar image processing test bed where it provides a 40x throughput improvement over previous discrete implementations. The multiply-accumulator wafer has also been configured as an FFT processor and a multi-channel CFAR filter.
Wafers implementing each of these functions have been integrated into a compact Doppler radar processor test bed.

A new wafer-scale architecture has been developed, the most sophisticated to date, which implements a SIMD multiprocessor array. The design comprises an 8x8 array of programmable processor elements embedded in a 9x9 array of memory modules. Each processor has direct access to its four neighboring memory modules through an array of three-port switches which provide path switching between memory and processors. Memory module capacity will be sufficient to store two 256x256 8-bit images in the 64 processor array. Individual cells for this design have been fabricated and tested; full wafer fabrication will begin next year. Using 2 μm features, this circuit will comprise an estimated 1-2 million working transistors on a 5" wafer.

Wafer-scale integration is being explored for implementing neural nets, since it is ideally matched to the extraordinary interconnect requirements of neuromorphic systems. A generic wafer-scale architecture is being developed which will be capable of implementing a wide variety of different network types. The network architecture for a particular application would be hard-wired after fabrication, by laser programming. As a first step in exploring potential wafer-scale implementations, a chip was designed and fabricated in the MOSIS foundry. The chip uses multiplying digital-to-analog converters to implement the programmable "synaptic" weights common to all electronic neuron models. Using these devices a simple neuromorphic system was built and tested which implements a Gaussian classifier for recognizing the first seven monosyllabic spoken digits.

LASER PHOTOCHEMICAL TECHNOLOGY

Important advances have been made in laser photochemical technology for solid-state device fabrication. In one area of application, the Laboratory is developing projection lithography with deep-ultraviolet excimer lasers in a configuration similar to step-and-repeat systems. Experiments have shown that excimer lasers can induce direct deposition and etching processes and can pattern materials with dry-etch resistance superior to that of current photoresists. A particularly promising material is diamond-like carbon which is being investigated as a self-developing excimer laser resist. Plasma-deposited films have been etched using a projected ultraviolet image (single 15-ns pulses at 193-nm wavelength). Linewidths as small as 0.13 μm have been obtained, which is more than five times better than that of refined optical steppers and superior to currently practical e-beam and x-ray lithographies for production of next-generation VLSI.

In a second application of laser photochemical technology, the Laboratory has established a unique capability for making accurate adjustments to high-frequency monolithic microwave integrated circuits. As fabricated, these circuits have unacceptable variations in device and circuit parameters which significantly degrade overall performance. Existing techniques for post-fabrication adjustments, such as wire-bonding of prefabricated trimming elements to the main circuit, are imprecise. As a flexible approach to achieving the same end, a laser-direct-writing technique has been developed in which metal (tungsten) lines may be added virtually anywhere in an existing circuit. The precision is on the 1- to 2-μm scale, offering control of
Superconductive analog technology is being developed for extremely wide-band analog and hybrid analog/digital signal processing. Superconductive tunnel junctions are used as mixers, comparators, and digital logic elements, and the low RF losses of superconductive thin films are exploited to provide long, compact electromagnetic delay lines. Matched filters, correlators, and track-and-hold circuits with multigigahertz bandwidth have been demonstrated, and 40-ns-long tapped delay lines have been used to produce a real-time spectrum analyzer with 10-GHz bandwidth, 40-MHz resolution, and 25-MHz spectral update rate.

The Laboratory's current superconductive integrated-circuit fabrication process is based on niobium and lead thin films. To improve the ruggedness of the circuits and to increase their operating temperature, a niobium-nitride process is being developed. As part of this effort, a feedback-controlled reactive sputtering technique has been demonstrated which reproducibly yields NbN of the proper stoichiometry.

Both bulk and thin-film samples of the newly discovered high-transition-temperature (~90 K) oxide superconductor YBa$_2$Cu$_3$O$_{7-y}$ have been produced at the Laboratory. For the further development of this family of materials, a multichamber ultrahigh-vacuum sputtering system is being constructed that will be equipped with instrumentation for materials analysis and measurement of the deposition conditions. Its use is expected to contribute to the science of sputter deposition and to the realization of practical circuits using these materials.

FLTSAT EHF PACKAGE

In 1982 the Department of Defense committed to a new satellite communications system called MILSTAR which was largely based on technology that had been developed at Lincoln Laboratory. In order to achieve an early capability, Lincoln Laboratory was asked to build two space payloads to be carried on FLTSAT spacecraft. These payloads are called FLTSAT EHF Packages (FEP).

The MILSTAR system will permit instant communication among many users, deployed worldwide, using small mobile terminals. The system provides a high degree of resistance of electronic interference. MILSTAR's capability accrues from the use of several technological innovations. It is the first satellite system to utilize the EHF radio band. All uplink data is demodulated on-board the satellite and remodulated onto its downlink permitting maximally efficient utilization of satellite transmitter power. Another innovation is an on-board access controller which connects uplinks to downlinks in dynamic fashion in accordance with user requests. This feature has been called a switchboard-in-the-sky.

Since 1982, Lincoln Laboratory has been building the two FEP flight packages which incorporate all the innovations described above. The first of
these payloads was launched in December 1986, has been verified to conform to all its specifications, and has been turned over to the Navy as an operational resource. The second payload is scheduled for launch in late 1987.

ADAPTIVE-OPTICAL TECHNOLOGIES

The Lincoln Laboratory adaptive-optics program comprises elements in atmospheric compensation and laser beam quality improvement. Previously, progress was reported in compensating atmospheric turbulence with apertures of 60-cm diameter. This work continues, and is aimed at experiments with an advanced system in 1987-88.

In 1986-87 significant progress was made in the use of adaptive optics to improve laser beam quality. In the technique used, a sample of the beam is focused into a pinhole and the power peaked up in the pinhole by adjusting actuators on a deformable mirror. The sensor and servo systems are based on a multidither principle, whereby each subaperture in the deformable mirror is coded at individual frequencies. This technique works quite well when the concept of a "wavefront" is ill-defined, as it often is with a multi-line laser. The approach is only applicable, however, when the laser is Continuous Wave (CW) or operates at a very high duty factor.

In related areas, the Laboratory is investigating the application of non-linear phase-conjugation techniques, such as stimulated Brillouin scattering, to atmospheric compensation and device-quality improvement.

CCD DETECTOR ARRAYS IN SPACE SURVEILLANCE

The Electro-Optical Space Surveillance Technology Program has been a part of the Laboratory's space surveillance activities since the initial technology development and successful concept demonstration of tracking deep space satellites with optical telescopes and high sensitivity television-type cameras. This program has continued with technical support to the Air Force in the deployment of five operational GEODSS (Ground-Based Electro-Optical Deep Space Surveillance) Sites (four now in operation) as well as the development of advanced technologies to support advanced surveillance concepts, both ground-based and space-based.

Early investigations at the Laboratory into the technologies and applications of visible band Charge Coupled Device (CCD) solid-state imagers has led to a project to develop a CCD retrofit camera prototype to replace the intensified silicon target vidicon camera currently used in the GEODSS System. A mosaic focal plane camera using fiber optic image reducers and CCD imagers suitable for complete retrofit to the GEODSS sensors has been built and field tested. Experimental results indicate that significant improvement in satellite detection sensitivity, search rate, and accuracy can be obtained with CCD sensors.

In addition to the use of CCD cameras for ground-based space surveillance, the Laboratory has initiated a program to define, develop, and test critical technologies associated with space-based visible sensor concepts for satellite surveillance. Technology development efforts include solid state CCD imagers, mosaic focal plane arrays and advanced digital signal process-
ing. The advancement of solid state imagers emphasizes improved resolution and low noise operation (20 electrons) at high clock frequencies (2 MHz) for high detection sensitivity. Since anticipated focal plane designs call for many large chips (250,000 pixels per chip) to achieve the required large fields of view, the development of high yield device technology is also being pursued.

The CCD camera systems being developed in these programs emphasize high sensitivity and fine resolution which have direct application to the field of astronomy. For example, the Laboratory has used these camera systems to detect earth-approaching asteroids and low altitude debris in conjunction with NASA.

WALTER MORROW, JR.
Project Athena

Project Athena is an exploration of the potential uses of high performance, networked graphics workstations in the MIT curriculum. Supported by major grants of hardware, software, maintenance and technical staff from Digital Equipment Corporation and IBM, Athena is in its fifth year of fostering innovative educational applications of computing throughout the Institute.

Most of the work during the past year at the Project continues to be in three distinct areas:

1. Encouraging, supporting and understanding the effects of faculty-based efforts in innovative uses of computing.
2. Developing a base of software running on heterogeneous hardware.
3. Installing and operating a large scale base of hardware so that new curriculum ideas can be tried and tested.

Activities in each of these areas are described in sections below.

INNOVATION IN THE CURRICULUM

Each semester Project Athena solicits proposals from the faculty (as well as from student groups with faculty advisors) for innovative uses of computing. After these proposals are reviewed by faculty/student committees, the most worthwhile are funded.

To date, Athena has funded 125 projects spanning all the schools and most of the academic departments. Funding for these projects has been raised from a range of sponsors as part of MIT's overall commitment to Athena. So far $8.714 million has been provided for curriculum development.

In the past year, a large number of educational applications have made substantial progress. A sample of these includes:

FOREIGN LANGUAGE PROJECT

Several parts of this project simulate foreign language environments. The student may converse with residents of these environments. These projects are based on use of the video workstation (described below) and artificial intelligence programming.

In the Spanish project, No Recuerdo, the student helps a Colombian microbiologist suffering from amnesia recover his memory so he may locate a misplaced sample of genetically engineered material that threatens to cause a pandemic of amnesia. The student converses through keyboard input with the characters on the screen, and tries to learn the truth from characters who give conflicting stories about past events.

In the French project, Entrez dans Paris, the student helps a young journalist find an apartment. Using screen menus, an ingenious answering machine, advertisements placed in local bakeries, maps of Paris and the metro, and a collection of floor plans and photographs of apartment interiors, the student moves through a series of encounters with the protagonist's friends and relatives, real estate agents, repairmen, and so on.

ARCHITECTURE AND PLANNING

Developments include innovation in teaching analytic methods with spreadsheets, linear programming and mapping. Students in the design studio experiment using solid modeling software to preview construction. Graphics software for site planning was developed. A geographic information system was developed that uses data from the U.S. Bureau of the Census. CAD systems make use of videodisc links. Students may access the Rotch Visual Collection of Boston architectural images using a video workstation. Film editing tools were developed on the video workstation.
COMPUTER AIDED THERMODYNAMICS
Software that allows students to construct visual models of thermodynamic systems in a computational environment. Data which are captured as the system operates appear in graphic form on the workstation screen in real time.

CIVIL ENGINEERING
A series of applications programs ranging from tutors (GEPSE Geology) that anticipate common errors and prompt students toward correct solutions to design modules (GrowlTiger) with which students can observe and test the behavior of structures under varying loads.

POLITICAL SCIENCE
This project simulates the difficulties in nuclear arms control using a sequential prisoner's dilemma game.

MUSIC
This project developed software that allows students to experiment with musical structures to discover principles of composition. This project has developed a music workstation that includes a sound synthesizer that puts an entire orchestra at the student's fingertips.

NEUROANATOMY
Using the video workstation, students may examine a collection of slides of samples of structures in the human brain, may retrieve sequences of a recorded brain dissection, or refer to a three-dimensional graphic representation of human brain structures stored on videodisc. These visual materials are coupled with software for self-instruction and drill.

Project Athena was the featured subject of Tech Day, 1987. The principal investigators of projects in Architecture and Planning, Foreign Language Learning and Thermodynamics presented their work.

SOFTWARE ENVIRONMENT INNOVATION
In the past year, most of the technical developments at Project Athena have been oriented towards building a stable computing system that will function effectively when there are thousands of workstations deployed around the campus.

The Athena computing system makes intensive use of data networking. The users rely on workstations which are clients of network-based servers. Work on the client-side has included:

1. Further development and refinement of the X Window System, with a new release scheduled in September, 1987. This new version, undertaken cooperatively with the MIT Laboratory for Computer Science, has already been adopted by every major workstation manufacturer in the United States and abroad.

2. Integration of the SUN Microsystems Network File System with modifications to improve that system's security.

3. Design of a programmer's toolkit that uses the X Window System and allows application developers to construct various graphics objects such as menus, scroll bars and text windows.

The server-side of the Athena system includes the following:

1. File servers-Athena uses file servers to hold computer system libraries, subject-related materials and the files of individual users. These servers are connected to workstations via the high speed, campus-wide data network. They allow users to access files independently of their location.
2. Name service-This service provides a consistent way of converting names that are meaningful to users into the information needed for computer access.

3. Authentication service-This provides a secure way for various network services to authenticate the identity of a user requesting that service.

4. Post office service-This service holds electronic mail messages for users until they request them.

5. Mail service-This server handles all electronic mail originating from an Athena workstation or destined for an Athena user. It primarily routes mail to the appropriate post office server or external gateway.

6. Notification service-This server allows workstation users to contact each other and provides a mechanism by which Project Athena can notify all users of system shutdowns, maintenance and other actions which affect service.

7. Print service-These servers each manage one or more laser printers. They spool print output from workstations and control the actual printing.

8. Database service-This provides a location for the management of databases shared over the network.

9. The service management system-This system controls the configuration of all the other services. It includes data on users, mailing lists, access control lists and the names of various services. It periodically updates each of the servers by sending needed configuration information to each server.

The goal is to have this new computing environment fully operational for the start of the Fall, 1987 semester.

HARDWARE ENVIRONMENT INNOVATION AND EXPANSION

Significant developments in the past year include:

1. Development of the Athena video workstation. By outfitting a MicroVAXII or IBM PC/RT with a high-resolution graphics color monitor and adding a Parallax analog-to-digital conversion board with a 2Kx2K frame buffer, we are able to display still or motion video (30 frames per second) in screen windows.

A pilot video cluster will open in the Building 11 facility in the fall semester of 1987. The workstations will be able to display visual information from a variety of sources: videodisc, CD ROM, cable TV, and so on.

2. Installation of Athena workstations in five living groups, including three off-campus fraternities.

3. Acquisition and installation of high-quality projection equipment capable of displaying images from a computer monitor.

4. Renovation of the Athena workstation clusters across campus. Old timesharing terminals have been replaced by powerful 32-bit processor workstations. The total number of Athena workstations in place by Fall, 1987 will be 650.

STEVE LERMAN
The Francis Bitter National Magnet Laboratory (FBNML), with support from the National Science Foundation, operates a high magnetic field facility available, free of charge, to qualified scientists throughout the country. The laboratory also designs and builds magnets, and performs research in condensed matter physics, condensed matter chemistry, and biophysics.

**Highlights of Current Research Programs Include:**

1.) **High T_c Superconductors.** Resistivity measurements have shown that La_{2-x}Sr_xCuO_{4-y} may have an upper critical field as large as 140 T. In Y_{2-x}Ba_xCuO_{4-y}, estimates of H_{c2} range from 80 to 320 T; a fraction of this material is still superconducting above 45 T at 77 K.

2.) **Fiber Optics.** A fiber optic system has been used to perform Raman scattering experiments in the hybrid magnet (30 T), and at low temperatures (0.3 K). In the latter, a dramatic increase of the magnetic polaron energy was observed in n-CdMnSe below 2 K.

3.) **Magnetic Resonance Imaging.** The laboratory completed construction, with IBM support, of a unique system for magnetic resonance imaging and spectroscopy of humans. It has a field homogeneity of two parts per million within the scanning region, and a novel set of pulsed-gradient coils that cancel all eddy currents while maintaining gradient linearity and field homogeneity. This system is now being used for medical and biological studies in both imaging and spectroscopic modes.

4.) **Spin Polarized Atomic Hydrogen.** High field (20 T), low temperature (600 mK) compression experiments were used to determine the three body recombination rate of spin polarized atomic hydrogen. The high magnetic field sufficiently suppresses the recombination that a search for Bose-Einstein condensation may become feasible.

**SUPERCONDUCTIVITY**

In collaboration with Professor Orlando, Department of Electrical Engineering and Computer Sciences who has a University-Industry grant with Bell Communications Research, we have investigated the upper critical fields of the new high T_c superconductors including La_{2-x}Sr_xCuO_4 with critical fields up to 140 T, Y_{2-x}Ba_xCuO_{7-y} with upper critical fields extrapolated to 320 T. These first results demonstrated very high field properties of these new materials.

We have also completed extensive work on the upper critical fields and anisotropy limits of the high T_c superconductors RE_{1}Ba_{2}Cu_{3}O_{7-y} where RE = Nd, Eu, Gd, Dy, Ho, Er, and Tm. The transition temperatures and critical fields are relatively insensitive to the rare earth ion; however, the critical field is not proportional to the measured resistivity which indicates that the measured resistivity is not an intrinsic property of these superconductors.

A cooperative program with Supercon, Inc. has been carried out on a Small Business Initiative Research (SBIR) grant funded by DOE to Supercon, Inc. for powder metallurgy processing of Nb_3Sn materials as high field superconductors. The technology transfer demonstrated that this process is feasible for commercial production.

In collaboration with C.Y. Huang of Lockheed and P. Chu of the University of Houston, we have found indications of superconductivity in a rare-earth-barium-copper-oxygen sample at 225 K.

The superconductor YBa_2Cu_3O_x (T_c=92K) and related compounds have been synthesized and studied. For YBa_2Cu_3O_x the magnetic field dependence of electrical resistance and fluctuations were studied from 300 K to 4.2 K; the energy gap was measured at 4.2 K using a scanning tunneling microscope.

We have produced high-quality sintered pellets of the high-T_c superconductor YBa_2Cu_3O_x and have measured their critical magnetic field up to 23 tesla. Tunneling measurements using a squeezable junction technique and a point contact technique indicate an energy gap 2\Delta of about 3.5 kT_c.
HIGH-FIELD MAGNETOMETER.

A new sensitive magnetometer was developed for use in the high-field facility. The instrument is a modified Foner magnetometer, which overcomes the field-noise and vibration problems associated with the Bitter magnets. The new magnetometer has been used in a variety of experiments in fields up to 23 T. These include measurements of the magnetization of semimagnetic semiconductors, heavy fermions, intercalated graphite, and several new high-Tc superconductors.

THIN FILM SUPERCONDUCTIVITY.

We have observed a magnetic proximity effect in a superconducting thin film covered with a sub-monolayer metallic rare earth overcoating. In addition to the expected pair breaking, a large enhancement of the internal magnetic field in the superconductor was observed using a spin-polarized tunneling technique. An applied magnetic field of 0.1 tesla produced a 2.0 tesla magnetic field in the superconductor.

LOW TEMPERATURES AND HIGH MAGNETIC FIELDS.

The mission of the Low Temperature and High Magnetic Field Facility at the FBNML is to provide the unusual combination of very high magnetic fields and very low temperatures for the fundamental study of condensed matter systems. Highlights of developments at the facility in the last year may be divided into three sections: facility development, advances in instrumentation, and scientific progress.

Facility Development: The new top-loading dilution refrigerator is now in regular operation for both outside and in-house users. The ability to change experiments within about a day is a dramatic improvement over the several days required for conventional dilution refrigerators. A room-temperature access superconducting magnet and mobile computer based data acquisition system have also been made available over the past year.

Advances in Instrumentation: Several devices are in development for use with the new top-loading dilution refrigerator: high sensitivity magnetometers which can operate at low temperatures and in magnetic fields to 20 tesla are now in operation. A calorimeter is now being tested and a novel computer based technique for operating it has been developed. A new optical probe for the top-loader has been ordered and should be available for optical measurements on a wide variety of condensed matter systems in the Fall.

Scientific Progress: Progress has been made in the understanding of the physical properties of novel condensed matter materials such as: magnetic behavior of several heavy electron superconductors as well as the new "high critical temperature" superconductors. Heat capacity measurements have been made on organic conductors which display several magnetic field induced phase transitions. In our original dilution refrigerator a very difficult experiment on the quantum gas, spin-aligned atomic hydrogen, is now in progress. These various experiments involve dozens of researchers from many institutions.

Most of our work has concentrated on using magneto-optics to study diluted magnetic semiconductors (DMS) such as (Cd,Mn)Te and (Cd,Fe)Se, and two-dimensional systems such as GaAs/(A4,Ga)As. In DMS materials the exchange interaction between carrier spins and magnetic-ion spins produces strong magneto-optical properties such as large bandgap tuning with magnetic field, large Faraday rotation and magnetic polarons. Optical experiments on high-mobility, doped GaAs multiple quantum wells in fields to 30 T and temperature to 0.3 K allow us to investigate the incompressible quantum fluid giving rise to the fractional quantum Hall effect. We have developed a number of fiber-optic systems, allowing us to do Raman scattering, Faraday rotation, and photoluminescence measurements in very large magnetic fields (65 tesla) and at low temperatures (~0.3 K).

GROWTH AND PROPERTIES OF MANGANESE-ALLOYED II-VI SEMICONDUCTING COMPOUNDS.

Intentionally doped Co1-xMnxTe crystals with composition 0.01 < x < 0.6 were grown by the vertical Bridgman technique. Systematic studies were made of: (a) the mechanisms for substitutional doping of the acceptors Cu, Au, P and As; (b) interaction of native defects with foreign impurities; and (c) the binding energies of various defects.

LIQUID CRYSTALS

The effects of a small amount of an added alcohol on anisometric micelles were studied, indicating a substantial increase in micelle diameter. Micelles composed of two similar surfactants of different lengths were studied, showing a maximum size at an intermediate concentration. High fields were used to investigate the rod-to-coil transition in the polymer poly-4BCMU, and the relative degree of aggregation in solution versus time was obtained. Several novel surfactant materials were investigated or are currently under investigation, including a disk-shaped molecule and a molecule which forms a gel phase at ultra-low concentrations. The micellar liquid crystal CsPFO was studied near the nematic-smectic A tricritical point, and was shown to exhibit behavior characteristic of Fisher renormalization.
SOLID STATE MAGNETIC RESONANCE

During the past year, we have been concerned with four different areas of research. First, we have continued our development of methods for studying protein dynamics with deuterium NMR and magic angle spinning (MAS). Specifically, we have developed methods for calculating MAS intermediate exchange lineshapes and $^{2}H$ T$_{1}$ anisotropies and applied these to several interesting systems. Second, we have trapped photointermediates of the membrane protein bacteriorhodopsin and examined its NMR spectra, as well as spectra of $^{13}$C of retinal-labeled rhodopsin. Third, we have begun to develop methods to acquire high resolution spectra of lipids and peptides in lipid membranes. Finally, we have recently received a grant to construct a high field DNP/NMR and EPR machine.

NEW NMR METHODS

Nonlinear NMR Excitation sequences have been discovered, which have the property of allowing suppression of a spectral frequency band without disturbing the rest of the spectrum appreciably. They have been demonstrated to be useful for measuring the NMR spectrum of dilute biomolecules in aqueous solution, where the water peak must be suppressed to obtain a high-fidelity spectrum. In addition, a method has been developed which should assist in structural determinations in amorphous solids. The combination of magic angle sample spinning with weak rf irradiation at the rotary resonance condition allows measurement of small heteronuclear dipole couplings which are practically inaccessible by any other method.

MAGNET TECHNOLOGY

1.) Continuing development of high field NMR.
2.) Pulsed field construction and analysis; 50 T generated.
3.) Quench protection analysis of superconducting magnets.
4.) Monohelix insert coil for hybrid magnet contributing toward dc field record.
5.) High field split pair water-cooled magnet; 17 T design point.
6.) Dummy winding for NbSn section of the next FBNML hybrid magnet.

The radially-cooled hybrid systems have operated with unprecedented reliability and performance. The 53 mm bore system generates 27 teslas, employing a monohelix insert. The 33 mm system has generated 30.8 T; with holmium pole pieces it should generate over 34 T.

LOW FIELD LABORATORY

Extensive magnetoencephalographic measurements have been made of several classes of epileptic subjects. Preliminary analysis indicates that it is possible to localize epileptic foci (sources) in the brain using these measurements. A computer modeling study of the effects of the skull and head shape in the accuracy of source localization has been started.

MAGNETISM IN A EUKARYOTIC ORGANISM

We reported the first observation of magnetite and magnetotaxis in a eukaryotic cell - a single-celled euglenoid alga collected in Brazil.

POSTDOCTORAL FELLOWSHIPS

Dr. Huub deGroot (Netherlands Organization for the Advancement of Pure Research) - Solid state magnetic resonance; Mossbauer effects.
Dr. Bennett Goldberg (Myron Bantrell Charitable Trust) - High field optical measurements on semiconductor superlattices.
Dr. Michael Graf (IBM Corporation) - Experimental condensed matter physics at low temperatures and high magnetic fields.
Dr. David Holtzman (National Institutes of Health) - Mechanisms of cytotoxic brain edema.
Dr. Terrence Oas (American Cancer Society) - Solid state magnetic resonance of membrane-spanning peptides.
Dr. George Schmiedeshoff (IBM Corporation) - Low temperature physics.
Dr. Steven O. Smith (National Institutes of Health) - Cellular and molecular biology.

PETER A. WOLFF
During the academic year 1986-87, the Center for Cognitive Science continued to foster interdisciplinary research in human cognition, primarily through development of the Human Subjects Laboratory and the various programs outlined below. These activities were coordinated through the Center's Working Group, which, by means of a committee structure, reviews all proposals and approves expenditures for those programs judged worthy of support. This year the membership of the Working Group has been expanded to include four new members in the areas of linguistics, philosophy, and electrical engineering and computer science.

**THE MULTI-USER LABORATORY**

Since 1981, the Multi-User Laboratory of the Center for Cognitive Science has provided the cognitive science community at MIT with computational facilities for data analysis, simulation, stimulus preparation, linguistic analysis, and on-line control of experiments on perception, cognition, and language. The Laboratory is the principal experimental research facility for graduate students and faculty in linguistics and in human experimental psychology and serves the visiting scientists and postdoctoral fellows in residence at the Center and in the Department of Brain and Cognitive Sciences each year. In addition, undergraduates taking Subject 9.63, "Laboratory in Cognitive Science", use it to carry out their weekly lab assignments.

The central facility in 20C-231 contains a PDP 11/44 and a Microvax II running Berkeley UNIX, several microcomputers dedicated to real-time control of experiments, subject testing stations equipped with video monitors, headphones, tape recorders, and eye-movement recording equipment, plus associated peripherals such as printers, plotters, and tape drives. In addition, the Multi-User Lab maintains several satellite subject-testing labs in the Department of Brain and Cognitive Sciences (E10). These labs are connected to another Microvax II, a clone of the one in Bldg. 20. Programs for on-line control of experiments use locally-developed commands that insulate the user from idiosyncrasies of the hardware interface to lab peripherals; for example, there are commands that show text at a given screen position for a specific duration, or that advance a slide projector and open a shutter.

The 1986-87 year marks a watershed in the development of the Center Lab. The complex, antiquated, and labor-intensive computers that had served the lab since 1981 have been replaced by inexpensive, easily-maintained and more powerful substitutes. The PDP 11 has been replaced by two Microvax II's, one in Bldg. 20 and one in E10. Finally, the LSI-11 based microcomputers used to run experimental stations are being replaced by machines in the IBM XT/AT family, using standard Project Athena configurations. In addition, the software designed to run experiments has been completed: parts of it were developed in conjunction with subject 9.63 (Laboratory in Cognitive Science) under the support of a grant from Project Athena to Professor Steven Pinker. It is anticipated that as a result of these changes, the demands of the Center Lab on personnel and financial support will decrease from previous levels.

Other developments during the past year include:

- The Lexicon Project, supported by a grant from the System Development Foundation, has transferred its work on the construction of computerized dictionaries for several languages into the Center.
- Facilities for laser printing were installed in Buildings 20 and E10.
- Software for the monitoring of eye-movements, for the control of random-access slide projectors, and for the display of 3-D graphic images, has been written.
- A program to edit and analyze speech waveforms has been implemented on microcomputer hardware.
- LISP has been installed.
- The full Child Language Data Exchange System, containing on-line transcripts of the spontaneous speech of children learning various languages and of programs to search and manipulate these transcripts, has been installed. This system was developed at Carnegie-Mellon University under the support of the MacArthur Foundation and is expected to revolutionize the study of language acquisition.
- A LISP program designed to tag language transcripts with the part-of-speech categories of each word, and to search for and extract all sentences matching a user-specified syntactic pattern, has been developed.

- BMDP, a full statistics package, was installed.

RESEARCH

The major research project in the Center during the past year has been the Lexicon Project. The work being done in this project has two aspects, one descriptive, the other theoretical. Descriptively, the Project is collecting and documenting the lexical resources of three Non-Indo-European languages; namely, Tamazight Berber (Morocco), Warlpiri (Central Australia), and Winnebago (Wisconsin). Theoretically, the Project is involved in the general effort within theoretical linguistics to deepen understanding of human lexical competence. English and other well-known languages figure prominently as objects of this research, as do the Non-Indo-European languages mentioned above. This work is, therefore, largely comparative and seeks to elaborate a general theory of the lexicon and its relation to other components of grammar.

During the four years of the Project, work has continued on the implementation of a framework that will allow us to build a computer-based database for English verbs. This database will contain information about the properties of verbs that we consider relevant to the realization of ideal lexical entries and will form a foundation for further work on lexical semantics and the construction of a lexicon which will complement the important work on parsing being done here at MIT. As part of this effort, the Lexicon Project is compiling a set of resource materials on English lexical organization, focusing on verb classification and diathesis alternations, which will be put out in the Lexicon Project Working Papers series.

THE VISITOR SELECTION COMMITTEE

During the academic year 1986-87 the Center hosted 11 postdoctoral fellows; one in psycholinguistics, nine in linguistics, and one in spatial-visual cognition. The Center also sponsored eight visiting scientists: two in psycholinguistics and language acquisition, two in psycholinguistics, one in linguistics, one in phonology, one in computer science, and one in philosophy.

THE AFFILIATE PROGRAM

The Center continued its Affiliate program, which provides formal status for individuals who are connected with Center research but are not in residence at MIT. Affiliates are individuals who are working actively in the field and observers of the field who wish to have an affiliation with the Center.

THE MEMBER PROGRAM

The Center maintained its Member program which provides individuals within the MIT community formal affiliation with the Center. The program was designed for individuals whose interests significantly overlap with, and support the intellectual goals of the Center. At present there are eight designated Members of the Center: Professor Kenneth Hale of the Department of Linguistics and Philosophy, Professors Emilio Bizzi, John Hollerbach, Whitman Richards and Jeremy Wolfe of the Department of Brain and Cognitive Sciences, Professor Suzanne Flynn of the Foreign Languages and Literature Department, Dr. Stefanie Shattuck-Hufnagel of the Research Laboratory of Electronics, and Dr. Lucia Vaina in Health Sciences.

SEMINARS AND COLLOQUIA

During the 1986-87 academic year the Center continued to support three kinds of seminars. The Center for Cognitive Science Seminar series, a monthly seminar, is open to the Cambridge community at large and presents papers on a variety of topics relevant to the Center. The papers are distributed to seminar participants before the meeting. At the seminar itself, a commentator or commentators present the paper, the author follows with comments, and the paper is then thrown open for general discussion from the floor. Last year over 500 members of the community attended a total of nine seminars. Vision Lunches are weekly lunch-time talks sponsored jointly by the Center for Cognitive Science and the Department of Brain and Cognitive Sciences and held in the conference room of the Brain and Cognitive Sciences Department. Twenty-two lunch talks were given last year. Finally, the Lexicon Project Seminar was a year long weekly seminar devoted to talks on the theory of lexical entries, drawing on a wide variety of languages, including Warlpiri, Winnebago, Berber, and English. Twenty-two Lexicon Seminars were given last year.
THE OCCASIONAL PAPER PROGRAM

The Center for Cognitive Science sponsors a series of Occasional Papers. The papers attempt to inform fellow workers in the field of the current research being done at the Center. To date 34 Occasional papers have been published.

THE LEXICON PROJECT WORKING PAPERS

Lexicon Project Working Papers are sponsored by the Center. These papers describe the work carried out at the Center in conjunction with the Lexicon Project. The aim of these papers is to report current research on the Lexicon Project. To date, 16 papers have been published.

PUBLICATIONS

The Center for Cognitive Science has supported a variety of publications by making its resources available to visiting scientists, postdoctoral fellows, predoctoral fellows, and to affiliated faculty. As of the end of the academic year 1986-87, a total of seven books and approximately 130 articles have been published as a result of Center support.

SAMUEL JAY KEYSER
The Center for Materials Science and Engineering (CMSE) was founded in 1960 for the study of the structure and properties of materials. Currently, major funding for the Center is provided through the Materials Research Laboratory program of the National Science Foundation (NSF). The Center operates major research facilities which provide state-of-the-art instrumentation and the expertise of professional staff to foster research projects of the materials community at MIT. We also provide seed funding for a small number of exciting projects for faculty seeking to develop new ideas, and we fund collaborative research on major problems in materials science. Last year we reported funding research in five major thrust areas.

Seed funding for 19 research projects was provided during fiscal 1988. A major event in the materials world during this past year was the discovery of superconductivity in some transition metal oxides at room temperatures as high as 90 Kelvins. This raised the possibility of superconducting devices that could be cooled with liquid nitrogen instead of liquid helium. There is even hope that much higher transition temperatures may be achieved. The Center provided seed funds for MIT scientists to begin work on these materials and they have already produced some interesting results, including large single crystals and a promising novel method of synthesis in which suitable alloys are first formed, then oxidized.

Development of our central facilities to support the research of MIT scientists continued. A major initiative is the establishment of a joint facility with Harvard University for characterization and analysis of surfaces. Capabilities will include Rutherford back scattering, secondary ion mass spectroscopy, x-ray photoelectron spectroscopy, and Auger electron spectroscopy. The capital cost of the equipment exceeds $2,000,000, and the facility will be available to the materials research community at both universities. Our new facility for the production of materials by rapid solidification techniques began full-scale operation and will be helpful in preparation of the new high temperature superconductors. We also established an x-ray diffraction facility in collaboration with the department of Materials Science and Engineering. The facility contains two rotating anode sources and is used for both laboratory instruction and research. The facility is operational, although the computer-controlled operating and data analysis systems have not yet achieved their full potential. During the first year of our x-ray scattering spectrometers at the Brookhaven National Synchrotron Light Source, a number of significant experiments were carried out. These include studies of free standing liquid crystal films, icosahedral glasses (quasicrystals), oxygenated and hydrogenated tungsten <100> surfaces, monolayers of krypton and xenon on single crystal graphite substrates, roughening of the <100> surface of silver crystals, and magnetic scattering of x-rays in MnF₂, and MnₓZn₁₋ₓF₂.

Below, we briefly outline the research activities of our five thrust areas during the past year. The names and departmental affiliation of the individual researchers are given at the end of each section.

Deformation and Fracture at High Temperatures.

The goal of this thrust area is to advance basic materials science by obtaining a sound understanding of the mechanistic basis for the deformation and fracture behavior of metallic alloys at high temperature, as well as to develop mechanism-based laws for the rate of deformation and damage development under various conditions. This basic understanding can be used to extrapolate empirical testing results to different operating conditions and also provide a way to predict remaining life and current state of damage in parts with an uncertain history.

In a pioneering study that has combined the expertise of much of the thrust area, the rates and mechanisms of damage were studied in protective aluminide coatings on γ-γ' single crystalline substrates subjected to realistic conditions of thermal cycling. This has shown the essential effect of strain ranges on degradation by surface roughening. Other achievements include the development of state variable based constitutive laws for primary creep and creep transients in nickel derived from experimental studies on polycrystals and single crystals as well as constitutive laws for time dependent deformation at high homologous temperatures, derived from experiments on single crystalline oxide dispersion strengthened ferrous alloys, and demonstrating that the creep resistance in γ-γ' alloys derives from the severe restrictions of plasticity in very narrow, sub-micron sized γ gaps.

Defects in Semiconductors

Deviations from the perfect structure of single-crystal, defect-free semiconductors cause scattering, trapping, and recombination of electrons and holes. On the one hand, these phenomena limit the performance of semiconductor devices such as lasers and transistors. On the other hand, they give rise to scientifically interesting new phenomena, such as hopping conductivity. The goals of the research in the general area of defects in semiconductors therefore fall into two categories. The first is the identification of defect structures that are most important in a particular material or class of materials. The second is the understanding of the new electronic phenomena that arise in materials with high densities of defects.

Theoretical work in the thrust has led to the prediction that in a doped and compensated semiconductor, there is a new state of electrons, a Coulomb glass. This state is thought to result when the electrons distribute themselves among the impurities in a way that minimizes their Coulomb interaction. However, since there are an infinite number of such arrangements, the system forms a glass. Experiments have been done using a pulsed CO2 laser to excite the carriers into a fluid state and then let them quench into the glass state. Preliminary results show a surprising phenomenon. After photoexcitation, the conductivity is high (about 10 times higher than the dark value) and remains high for times as long as several milliseconds. After this delay the conductivity suddenly drops to the dark value in a few milliseconds. This phenomenon is only observed in compensated samples and is probably, therefore, related to the Coulomb interactions among the electrons in the impurity band. This may provide the first evidence of the new state of the electron gas.

The group was shocked by the sudden passing of Professor Adler this spring.


Phases and Phase Transitions

This group was pleased by the award of the 1986 Oliver Buckley Prize of the American Physical Society to Professor Robert Birgeneau for his studies of phase transitions in condensed matter. Equally pleasing was the award of the 1986 Polymer Society of Japan Prize to Professor Tanaka for his pioneering work on phase transitions and critical phenomena in polymer gels. The Center for Materials Science and Engineering has provided essential support for the prize winning work of both of these scientists.

Experiments using high resolution x-ray scattering and light scattering to study the structure of free standing liquid crystal films have been extended to very thin films in order to study the crossover from three- to two-dimensional behavior. Preliminary data analysis shows the disappearance of higher harmonics of the liquid crystal bond-orientational order parameter that one would expect on theoretical grounds for two-dimensional systems.

Progress in developing the theoretical and experimental tools to understand the structure of micelles, microemulsions, and colloids has been substantial. This has largely been due to the combining the results of several different experimental probes in order to test the theoretical models.

Faculty/Department: Professor C. Garland (Chemistry). G. Benedek, A.N. Berker, R. Birgeneau, T. Greytak, J.D. Litster, T. Tanaka (Physics), S-H. Chen (Nuclear Engineering), and A. Aharony (visitor to CMSE).

Polymers

The novel synthesis of polymers using transition metal based catalysts has been the goal of several members of this thrust area. Catalysts, based on W, Ta and Mo organometallic chemistry, which attack carbon-carbon double (or triple) bonds only in cyclic molecules, have been used to prepare, via a ring-opening metathesis reaction, "living" polymer systems. The catalyst does not attack the double or triple bonds in the resulting polymer, making this an extremely clean reaction so that branching and cross linking do not occur. Recently preparations are polymers based on cyclopentene and norbornene, and block copolymers of these two. Films of these have been made and the properties are being characterized. The rates of polymerization and the lack of side reactions are such that extremely low polydispersity for the resulting polymers is found. This new chemistry opens up many new possibilities in polymer synthesis. Efforts are now underway to synthesize polyacetylenes and polydiacetylenes.

In addition, the controlled modification of polymer morphology has been used to produce a high density of energy absorbing centers, thereby making the polymer extremely tough. Currently, the varied inelastic behavior in semicrystalline polymers is being studied to achieve even higher toughness. Also, the deformation mechanisms in both crystalline and amorphous phases are being being studied.

Faculty/Department: Professors R. Schrock, R. Silbey, M. Wrighton (Chemistry), R. Cohen, U. Suter (Chemical Engineering), and A. Argon (Mechanical Engineering).
Innovations in Steel Technology

This is a recently formed group which seeks to provide the scientific basis of a new steel technology aimed at specific property objectives that are important to industry.

The group has made progress in developing ultrahigh-strength steels. These are the materials used for critical applications in, for example, aircraft landing gear and helicopter rotor hubs. Existing steels have an ultimate tensile strength around 300 kilopounds per square inch (ksi), and toughness of 55 ksi in\(\frac{1}{2}\). However they have a serious drawback because of stress corrosion; the hydrogen ions available in a humid atmosphere will lower the toughness to 10 ksi in\(\frac{1}{2}\). Helicopter rotors require a toughness of \(\sim 20\) ksi in\(\frac{1}{2}\), and there have been several recent catastrophic failures which caused grounding of army helicopters for some time. These, and related failures, prompted an article on 'killer steels' about a year ago in the "Wall Street Journal".

One of the goals of the group has been to understand the microstructural and grain-boundary chemistry changes that could be made to improve the properties of these steels. By designing a microstructure that would resist fracture, while also addressing the problems of grain-boundary chemistry, they produced dispersion containing rare-earth oxy-metalloid compounds with hardenability enhancement by molybdenum. Sulphur and phosphorus, which normally embrittle grain boundaries, were "gettered" into stable dispersed particles which significantly increased the resistance to stress corrosion cracking.

The necessary grain size and uniformity of the steels were controlled by using rapid solidification techniques developed earlier at MIT. Measurements on preliminary samples show ultimate tensile strength of 300-320 ksi and toughness of 60 ksi in\(\frac{1}{2}\). More importantly, the toughness in a humid atmosphere is in the 20-60 ksi in\(\frac{1}{2}\) range. The next generation samples of the newly designed steel are expected to show even greater improvement. These first results indicate promise in using basic scientific knowledge to design steels of the desired properties, and should pave the way to a considerable improvement over more empirical approaches.

Faculty/Department: Professors S. Allen, M. Cohen, M. Flemings, G. Olson, and J. Vander Sande (Materials Science and Engineering).

J. DAVID LITSTER
The City Council of Cambridge has become a focus for the continued controversy regarding animal usage in biomedical research. Several versions of proposed ordinances have been submitted to the Council for deliberation and public debate. If passed, the "animal rights" ordinances would significantly impede biomedical research in the City of Cambridge. It is the stated position of the Institute that sufficient oversight and review is in effect to assure the humane care and treatment of animals at M.I.T. Routine inspections by veterinarians employed by the USDA and Commonwealth of Massachusetts have provided outside peer review and approval of the MIT animal resource program. In addition, DCM veterinarians and other members of the Institute Animal Care Committee routinely visit animal facilities and research laboratories. The Animal Care Committee provides written assurance that all animal related research at MIT conforms to humane care and use standards as promulgated by the Federal Animal Welfare Act and NIH regulations.

Animal related research at MIT continues at a vigorous pace; a vivid testimony to the importance of these activities in the quest for new knowledge in the biomedical sciences. Increased daily census of laboratory animals (average census has increased 12% from last fiscal year) required the addition of 3 animal technicians and a surgical nurse. An assistant facility manager also is now being recruited.

The Division maintains an active interest in training individuals interested in careers in veterinary medicine and the biological sciences. Several UROP students majoring in preveterinary sciences, summer veterinary fellows, and postdoctoral fellows are engaged in DCM veterinary and research activities. Because the Division faculty act as advisees for pre-veterinary students, these students are often involved in UROP projects, and receive priority in terms of space available in our laboratories. The average number of UROP students is one-two per semester.

The Division began accepting summer veterinary fellows in 1977. Since then we have enrolled 24 students into the program. Of that number, 3 are still in veterinary school, 12 (57%) have entered post-DVM graduate training, 9/12 (73%) in laboratory animal medicine, or comparative pathology, and 3 in post-graduate or residency programs in veterinary medicine. These figures reflect our interest and willingness to participate in training, and that our program has exerted a positive influence on the post-graduate interests of the participants. In addition, to date, five postdoctoral fellows have completed their residency, and DCM has three trainees currently enrolled in the DCM postdoctoral program. Of the five students, four have completed their residency in laboratory animal medicine and one transferred to the Harvard comparative pathology program after completing one year in our program. Because of our long standing interest in training in comparative medicine we were asked by NIH to submit a post doctoral training grant in laboratory animal medicine. The proposal has been submitted and if funded will sponsor 6 trainees.

For several years, DCM has been studying the biology and diseases of the ferret. In addition, we have on several occasions promoted the ferret as an alternate animal model, in lieu of the dog and cat, for studies in biomedical research. The ferret is gaining in popularity as an animal model, not only at MIT but nationwide. In response to their increasing usefulness, we are happy to announce the completion of a text entitled "Biology and Diseases of the Ferret" to be published in 1988 by Lea & Febiger. This text will provide the investigator the existing data base on diseases encountered in the ferret as well as salient biological characteristics of these animals.

The Division's research program has matured substantially in the last 2 years. Members of the Division are now involved as PI's or CoPI's in 8 NIH, NCI or other federally supported research activities. An additional 2 grants are pending review. The major thrust of research continues to be in the area of gastrointestinal disease. During the past year, DCM published 18 articles, monographs or chapters and has an additional 19 articles in press.

JAMES G. FOX, DVM
The main function of the Energy Laboratory is to encourage and assist research on a broad range of energy issues, emphasizing multidisciplinary problems that involve people from most of MIT's academic departments. That research addresses one or more of the following four broad questions: 1. How can fossil fuels, particularly low-quality fuels, be burned more efficiently, economically, and safely? (The word "safely" emphasizes environmental and health considerations.) 2. How can fossil, nuclear, and renewable energy resources be converted to more useful forms of energy efficiently, economically, and safely? 3. How can energy-intensive materials and methods be improved or replaced? 4. What are the interactions among energy, the economy, and society?

Total volume of the Energy Laboratory during fiscal 1987 was about $11.9 million compared to $13.1 million in FY86 and $10.7 million in FY85. The 9 percent decline was anticipated as earlier programs phased down or were completed. Our sponsorship remains highly diversified with about half of fiscal 1987 funding coming from the private sector (about one hundred organizations) and about one quarter from the US Department of Energy; at one time DOE provided more than 60 percent of our support. Over 70 faculty plus more than 200 graduate and undergraduate students from 15 academic departments (plus other MIT units) participated in Energy Laboratory projects during the year; no one department accounted for more than 30 percent of our volume. That diversity helps to maintain the multidisciplinary character of research we seek, and that academic participation helps to weave our activities as closely as possible into the educational fabric at MIT.

The Center for Energy Policy Research sponsored the 1986 North American Conference of the International Association of Energy Economists at MIT on November 19-21, 1986. Mr. David O. Wood, the Center's director, was conference chairman. The program consisted of three plenary and fifty-five parallel sessions on energy industry organization and regulation, energy demand, and the interaction between energy and economic growth. A pervasive sub-theme of the meetings was analyses and commentary on the effects of the 1986 oil price shocks on energy supplies, demand, and economic development. Major presentations were made by MIT Professors Paul L. Joskow of the Department of Economics and Lester C. Thurow of the Sloan School of Management, Dr. Charles G. Stalon of the Federal Energy Regulatory Commission, and Mr. T. Boone Pickens of Mesa Petroleum Company.

Professor Carl R. Peterson of the Department of Mechanical Engineering and director of the Energy Laboratory's Center for Innovative Mining Systems was the prime mover in organizing the Mining and Excavation Research Institute (MERI) and was appointed its Technical Director. MERI was originally established as an arm of the American Society of Mechanical Engineers but is now a separate corporate entity. With both public and private funding, MERI will involve universities and industries in a collaborative effort of research examining a broad range of surface and underground mining and tunneling activities.

Two program heads at the Energy Laboratory were singled out for professional honors. Dr. Mary O. Amdur, head of the Laboratory's work on inhalation toxicology, received the Career Achievement Award of the Inhalation Specialty Section of the Society of Toxicology. Professor Janos M. Beér of the Department of Chemical Engineering was honored twice. Professor Beér, Scientific Director of the Energy Laboratory's Combustion Research Facilities, received the Alfred Egerton Gold Medal of the Combustion Institute and the Coal Science Gold Medal of the British Coal Research Association.

Specific research accomplishments during the year covered a large and diverse set of topics. Some of the topics of more general interest were summarized in our quarterly research bulletin, e-lab, under the following headings, grouped here in four categories:

Natural Gas

-- Overview
-- European supplies: large quantities at low cost
-- European demand: slow, predictable growth
-- European gas trade patterns
-- The value of gas contracts
Nuclear Electric Power

-- Nuclear plant performance: an international comparison
-- Predicting wear in steam pipes
-- Cleaning nuclear steam generators
-- Modular gas-cooled reactors (MGR)
  Small and safe
  Estimating potential releases
  Confinement, not containment
  Cost of the MGR
  Licensing the MGR
  The gas-turbine MGR

Synthetic Fuels

-- Burning coal liquids
-- Methane reactions on surfaces
-- Reactions of small particles suspended in space
-- Coal-water slurries: predicting how they flow
-- Wood conversion: controlling the liquids

Other

-- Breathing sulfur: animal lung damage
-- Measuring oil films

Information on all the projects active in the Laboratory during fiscal 1987 may be obtained from the report entitled Project Summaries, July 1, 1986 - June 30, 1987. The following paragraphs describe the major thrusts of the Energy Laboratory's principal research groups at the end of the year.

RESEARCH GROUPS

The Combustion Research Facilities program emphasizes parallel modeling and experimental investigation of combustion processes of gaseous, liquid, and solid fuels in both steady and unsteady operation. A special feature of the experimental studies is that fundamental flame data are obtained in large-scale pilot plant combustors in which the combustion-heat transfer processes closely simulate industrial practice (Professor Janos M. Beér, Scientific Director)

Research in the High-Temperature Reactions and Health Effects program concentrates on the oxidation and pyrolysis of fuels and on techniques for controlling emissions from these processes. Studies of the formation of mutagens in hydrocarbon combustion involve a team effort among engineering, analytical chemistry, and biological sciences. (Professor John P. Longwell, Program Director; Dr. William A. Peters, Program Manager)

The Synthetic Fuels Center is concerned with research on conversion of primary energy resources to liquid and gaseous fuels. Energy companies cooperate to support and offer guidance to the program. Current projects are investigating comminution of energy minerals, coal pyrolysis, desulfurization of not gases, reactions of microparticles, and dissociative adsorption of methane. (Dr. Malcolm A. Weiss, Director)

The Transportation Propulsion program conducts research related to improving conventional spark-ignition and diesel engines and on developing new engine concepts. Activities are based in the Sloan Automotive Laboratory and include fundamental and applied research on engine performance and emissions characteristics, engine fuels requirements, novel engine concepts and materials, and policy and technology studies. (Professor John B. Heywood, Program Director; Dr. Victor W. Wong, Program Manager)

The Energy Engineering program is a collaborative effort with the Idaho National Engineering Laboratory that focuses upon research in the engineering sciences needed to enhance energy use in technical industries. Active research areas include: thermal plasma materials processing; automated welding; engineering analysis and design methods; and fracture mechanics/fracture control. The research aim is to bridge the gap between the science base and existing industrial practice by providing methods, models, and data that will allow for improvement in technical products and processes. (Professor Kent F. Hansen, Program Director)

The Advanced Energy Materials program examines new and emerging technologies in such areas as electrodes and electrolytes for high-density batteries and fuel cells; synthesis of ceramic powders using laser heat sources; rapid solidification of molten ceramics; solar heating/cooling; amorphous photovoltaics; and broad-band antireflective coatings. (Dr. John S. Haggerty, Program Director)
The Energy Markets, Pricing, and Regulation program conducts research on the structure and regulation of energy industries and markets, and the interaction between energy markets and the macroeconomy. Current research focuses on the structure and regulation of the international petroleum and US electric utility industries; analyses of energy demand and the relationship between energy prices and economic growth in both developed and developing economies; studies of international oil, gas, and coal markets; and development and application of new methods for capital budgeting and energy project evaluation. (Mr. David O. Wood, Program Director)

The Center for Energy Policy Research focuses on policy research and analysis and on making results available and useful to policymakers. With support from its Associates, a wide range of US and foreign corporate and noncorporate interest groups, the Center holds conferences and seminars to bring together key government and private organizations to work on energy-related policy issues. The work of the Center is done by faculty and students from several MIT departments (particularly the Sloan School of Management and the Department of Economics), by professional staff members from the Energy Laboratory, and by specialists from the Center's Associates. (Mr. David O. Wood, Director)

The Electric Utility Program serves to inform participating companies about ongoing MIT research activities, to identify and discuss utility needs and priorities, and to develop research projects responsive to those needs. The member organizations currently participating in the program include 17 utilities; 10 other organizations involved in supplying fuel, equipment, or services to the industry; and one government agency. (Dr. J. Derek Teare, Director)

The Nuclear program has the following broad objectives: 1) to provide direct technical contributions to nuclear plant reliability and safety; 2) to investigate possible improvements in nuclear plant design for more efficient utilization of nuclear resources; and 3) to develop and communicate information to the public and nuclear power industry that will improve the efficient utilization of nuclear power. (Prof. Neil E. Todreas, Program Director)

Research in the Environmental program seeks to identify and reduce the environmental impacts of pollutant emissions to air, water, and land from energy-related facilities. It involves a diverse range of projects, including cooling and waste disposal systems for electric power plants, water management issues associated with coal development, impacts of acid rain, and local and long range effects of air emissions. (Professor James A. Fay, Program Director; Dr. E. Eric Adams, Program Manager)

The Center for Innovative Mining Systems was organized together with The Pennsylvania State University to conduct research on advanced mining systems. It initially emphasizes underground coal mining, focusing on the development of simplified systems for remote control, thus removing miners from regions of high risk. (Professor Carl R. Peterson, Director)

The Energy-Efficient Buildings and Systems program examines the behavior of existing buildings and components and seeks to develop new technologies with better energy efficiency. Current projects include studies of the transfer and accumulation of moisture in structures, air circulation in interiors, new envelope materials, and aging characteristics of closed-cell foam insulation. (Dr. Leon R. Glicksman, Program Director)

**PUBLICATIONS**

During the past year, Energy Laboratory research resulted in 36 technical reports and working papers and about 97 other publications (journal articles, workshop and conference presentations, etc.). Energy Laboratory Headquarters has available a complete list of reports and working papers as well as copies of Project Summaries and e-lab.

MALCOLM A. WEISS
INTRODUCTION

Health and medical problems are complex and difficult to study, let alone to solve along uni-disciplinary lines. The Harvard-MIT Division of Health Sciences and Technology (HST) is, by design, multidisciplinary. The division affords a quality and range of educational experience and of human and physical resources that neither university can provide alone, promotes inter-university and interdisciplinary collaboration, and provides an institutional framework for the joint efforts of scientists, engineers, physicians, and surgeons.

ADMINISTRATION

The administrations of Harvard and Massachusetts Institute of Technology have strongly reaffirmed the original goals of HST and have been supportive of their implementation. FY87 was the second year of operation of the HST Division under its new administrative structure. The new organization continues to work very well, and a number of new initiatives have been implemented. The Co-directors, Dr. Richard Kitz and Dr. Roger Mark, continue to be involved in all major management issues. The Executive Group, consisting of Professor James Adelstein (Dean for Academic Programs at Harvard Medical School), Professor Kenneth Smith (Associate Provost at MIT), and the Co-directors meet on a regular monthly schedule and the excellent inter-institutional communication and cooperation have been further enhanced. Several new members have been added to the Joint Faculty Committee, reflecting the continuing evolution of HST activities. An advisory committee is currently being formulated with eminent outside scholars to provide periodic assessment of the Division's academic and research functions to the Provost of MIT and the Dean of the Harvard Medical School.

Plans to establish an HST Academic Computing Facility in collaboration with Project ATHENA have come to fruition this year. A small complex has been renovated on the first floor of Building E25 to house the departmental cluster which includes nine IBM PC RTs, one IBM PC RT disc server, and one video workstation. Mr. Lesin Comeau has been appointed manager of the facility following his retirement from IBM. He was that company's principal representative to Massachusetts Institute of Technology and Brown University for the past decade. The computing facility will be interfaced later this coming academic year with Harvard Medical School and the Massachusetts General Hospital. Thus, it will facilitate teaching programs and communication among these institutions. Although obviously student oriented, the facility will serve to encourage HST faculty to develop programs of computer-assisted instruction with the help of Mr. Comeau.

An HST alumni association has been founded under the aegis of Professor Irving M. London, HST's immediate past director. He has written all graduates of the MD and PhD programs soliciting important demographic and other information. The first meeting of the alumni association is planned for October of 1987. Students' Day will precede and be linked to Alumni Day. As planned, students will present brief reports and participate in seminars concerning their research activities, and several joint alumni student workshops are planned. Appropriate social functions will be incorporated into the program.

ACADEMIC PROGRAMS

Biomedical Sciences

The HST/MD Curriculum Committee continues to evaluate all of its courses on a three year cycle and is planning an in-depth review of the entire curriculum during the coming academic year. Several major courses were redesigned including Quantitative Physiology, and a joint effort with the Department of Brain and Cognitive Sciences at MIT on the Human Nervous System. Dr. Leonard Groopman, an alumnus of the HST program, offered for the first time a new course entitled, "Medicine in Society: Historical Sociological Perspectives." Advanced clinical electives are being constructed for third and fourth year HST/MD students.

The MD Admissions Committee has recently completed an intensive but highly successful interview, ranking, and recruitment effort. Thirty new HST/MD students joined more senior colleagues for a total of 182 medical students in the program. Thirty-two are women, the remainder men. Sixty-two students are pursuing PhD programs in addition to their medical studies. A total of 16 students received the MD degree in June graduation exercises, 12 of whom graduated with honors.

Of particular concern is the increasing cost to students enrolled in the MD program. Although some scholarship funds are available via Harvard Medical School, they are small compared to the requirements. To meet the needs of the students for tuition relief, and to encourage their early involvement in
research, a research assistantship program was developed based on the MIT model. It is available to those students who are willing to commit 10 hours per week as a research assistant in a laboratory at MIT, Harvard, or the teaching hospitals. Because the program is highly leveraged, enough money to defray the tuition expenses of participating students can be generated. Additional funds are now being sought to make the program available to all who may wish to utilize it.

Biomedical Engineering and Physical Sciences

Eleven new students were admitted to the Medical Engineering/Medical Physics program, bringing the total enrolled to 50—13 women and 37 men. Four students completed the requirements for the PhD degree this spring.

A new doctoral program was launched this year in cooperation with the MIT Department of Applied Biology. The Applied Biology in Medicine doctoral program offers students an opportunity to combine areas of applied biological sciences such as biotechnology, biochemical engineering, and toxicology with an education in health sciences and technology. The program leads to a PhD degree awarded by MIT, and is intended for students who want to take a quantitative approach to research problems at the interface of medicine and applied biology. Professor Robert Langer heads this program.

RESEARCH

A major objective of the HST Division is to stimulate and facilitate inter-institutional collaborative research among faculty at MIT and HMS. We are currently appointing a senior faculty committee representing both institutions, which will serve to identify major themes for new collaborative research initiatives. In addition, this Faculty Research Development Committee will establish priorities and identify personnel and laboratories with requisite capabilities. We have recently recruited a Research Development Officer for the committee. He is Federico Welsch, MD, PhD, who spent 15 years as Executive Vice President of the Worcester Foundation for Experimental Biology. He is exceptionally well-qualified to implement the agenda of the faculty committee.

FACULTY

Currently three searches are underway for junior faculty posts at the Assistant Professor level. The Kieckhefer Chair is designed for an individual whose research efforts will be complementary to those of the Department of Biomedical Engineering at the Massachusetts General Hospital where facilities are available to work with Professor Ernest Cravalho, the Taplin Professor of Biomedical Engineering and Chairman of the MGH Department. Candidates are also being sought for the Cabot Chair, which is designed for a faculty person whose expertise and interest are in the area of artificial intelligence in medicine. A third undifferentiated search has begun to identify new and exciting research areas and candidates. It is anticipated that the Kieckhefer post will be filled this year and the remaining positions in 1988.

Dr. David Edell has been promoted to Associate Professor effective July 1, 1987. HST Promotions and Appointments Committee evaluated several applications for promotions of engineers at HMS. It recommended two for appointment at the Assistant Professor level and one for Associate Professor status. Dr. Farish Jenkins, Professor of Biology at Harvard University and Professor of Anatomy in HST, was awarded the Irving M. London Teaching Award bestowed annually upon that faculty member who, through excellence and dedication to teaching in the Biomedical Sciences curriculum, best exemplifies the goals and philosophy of the Harvard-MIT Division of Health Sciences and Technology.

RICHARD J. KITZ
ROGER G. MARK
The policy of the Mining and Mineral Resources Research Institute (MMRRRI) of MIT continues to be the utilization of available resources to support and encourage new initiatives in teaching and research that are related to minerals resources. Four graduate and four undergraduate students from the Departments of Civil Engineering, Mechanical Engineering, and Materials Science and Engineering have received support from the MMRRRI this year. Items of equipment have been purchased for the REMERGENCE Laboratory and for the Chemical/Process Metallurgy Group in the Department of Materials Science and Engineering. MIT continues its participation in the Bureau of Mines Generic Minerals Technology Centers for Pyrometallurgy and Respirable Dusts. Currently, a total of three research projects are funded through those centers.

Three faculty members, who are associated with the Chemical/Process Metallurgy activities of the MMRRRI, received recognition at the Annual Meeting of the AIME in Denver in February; Professor T. Eagar received the Champion H. Mathewson Gold Medal, Professor J. Szekely gave the Extractive Metallurgy Lecture, and Professor J. F. Elliott received the Educator Award of The Metallurgical Society. Professor Elliott also was made an Honorary Member of the Japan Institute of Metals at that Institution's annual meeting in Tokyo in March.

The Second International Conference on Innovative Mining Systems was held at the Pennsylvania State University in October. Professor Carl R. Peterson was co-director of the Conference. Professor Elliott delivered one of the two Key-Note Lectures on "The Need of Innovative Processes and Processing Methods in the Production of Metals" at the Schuhmann International Symposium on Innovative Technology and Reactor Design in Extraction Metallurgy.

JOHN F. ELLIOTT
The Haystack Observatory is a research center engaged in radio astronomy, geodesy, atmospheric science, and instrumentation development for radiometry and radar systems. Parts of its programs are conducted under the auspices of the Northeast Radio Observatory Corporation (NEROC), a consortium of thirteen educational and research institutions in the northeast. The Observatory receives financial support from the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the National Geodetic Survey (NGS), the National Radio Astronomy Observatory (NRAO), and the Department of the Air Force, directly and through the MIT/Lincoln Laboratory.

During the past year, the major accomplishments have been the enhancement of our scientific research programs by the addition of three post-doctoral positions, the establishment of a vigorous summer undergraduate student training program, and the modernization and upgrade of several of our facility instrumentation systems.

The main instrument at the Observatory, located at Westford, MA, is a 120-foot diameter paraboloidal antenna enclosed in a radome. It is heavily used by the astronomy community as a radio telescope with radiometers operating at frequencies from 1.6 to 49 GHz (18 - 0.6 cm wavelength). In the past year, the telescope was used by approximately 90 investigators from 40 different national and international institutions, and 42 articles were published in scientific journals based upon this work. The second Haystack Observatory conference on interstellar matter, "Molecules and Grains", was held at MIT on 10-12 June 1987 and was attended by 110 astronomers from the international community. The conference was combined with an event to honor Professor Alan Barrett of the MIT Physics Department.

Work continues on the Haystack antenna upgrade project to significantly improve the performance of the Haystack telescope in the frequency range from 20 to 50 GHz, specifically leading to an actual reflector surface realignment in 1988. Following replacement of the radome panels which was completed in 1986, an active temperature control system was installed on a thermally massive portion of the reflector surface - the splice plate, and system testing is now in progress. This system was required to correct for the lag in the temperature of the splice plate which produces differential surface expansion, and hence distortion of the reflector from its required parabolic shape. Radio holography is being used to measure the surface figure and a number of other projects are underway to improve antenna pointing and efficiency. Mechanical studies are also in progress in preparation for the 1988 surface realignment, which includes theoretical models for thermal and gravitational distortions as well as specific tasks related to the realignment. Our goal is to reduce the rms surface distortions to 0.5mm, thus doubling the telescope efficiency at 50 GHz.

In the past year, the 36-49 GHz (0.7 cm wavelength) maser amplifier receiver was used to search for methanol at 36.2 GHz leading to detection on a number of galactic sources, including the Galactic center source, Sgr B2. Silicon monoxide in the 43 GHz v=0, J=1-0 transition was studied in the Galactic center and in Orion A, and showed peculiar gas dynamics and density structure. Key observations of the carbon monosulphide line at 49 GHz have recently been made with the maser amplifier in several galactic and extragalactic radio sources that indicated the presence of high density gas. Haystack possesses a unique measurement sensitivity at this frequency amongst U.S. radio observatories.

Highlights of single antenna astronomy research in the past year in the 20-25 GHz band (1.3 cm) included the monitoring of the powerful water vapor maser source in Orion A which is an active region of star formation. This star flared to an unprecedented level of about 2x10^7 Janskys but has recently declined to its pre-flare status. In addition, dark clouds (regions of high extinction) and high velocity mass outflow sources in our galaxy were studied using the inversion transitions of the ammonia molecule. These transitions, which are closely spaced in frequency and detectable using Haystack's high resolution

*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, MIT, Polytechnic Institute of New York, Harvard-Smithsonian Center for Astrophysics, State University of New York at Stony Brook, Tufts University, University of Massachusetts, University of New Hampshire and Yale University.
spectrometer, require widely differing conditions for excitation and allow molecular cloud parameters such as temperature and density as well as dynamical information to be obtained. A correspondence is found in dark cloud regions between the occurrence of the ammonia molecule and the incidence of infrared sources.

Very Long Baseline Interferometry (VLBI) research capability in astronomy and geodesy was augmented this year by the inauguration of the Mark IIIA second-generation processor and operational use of high-density tape recording. In the last twelve months, 56 astronomical programs from 88 investigators representing 25 institutions were processed on the VLBI correlator at Haystack. Among the astrophysical results: the mapping of the point where a relativistic jet in the quasar 3C 205 collides with the intergalactic medium; VLBI measurements of the distance to Supernova 1979c, allowing an unbiased determination of Hubble's constant; and numerous new maps tracing the radio polarization and, hence, magnetic field structure of quasars during outbursts.

Improved algorithms implemented in the Mark IIIA processor allowed the first successful VLBI observations using an array beyond the confines of the earth. The collaborative effort between the Jet Propulsion Laboratory, NASA, and MIT/Haystack used the paraboloid antennas aboard NASA's Tracking and Data Relay Satellite (TDRS) to form an interferometer with earth-based antennas. Twenty-three extragalactic sources were observed on baselines up to 2.0 earth diameters. Results indicate the Inverse Compton scattering limit of $10^{12}$K brightness temperature may be exceeded in several sources; clearly, there are many sources with extremely compact structure which can be fruitfully investigated through space VLBI.

The Ridge computer system at Haystack has been heavily used for data reduction and image processing. Several hundred maps of radio sources have been produced on the system, and many of these appear in recent or forthcoming publications. The system capabilities were enhanced by the addition of a second 450 Mbyte disk drive, bringing the total on-line storage capacity to 0.9 Gbyte. The NRAO AIPS software package installation is now quite mature, and efforts are underway to transfer much of the VLBI post-processing burden from the existing VLBI specialty programs into AIPS.

An extensive study of high-redshift steep-spectrum radio quasars was continued last year. The large amount of mapping required for this project required a large amount of time on the Ridge computer, and is now about 85% complete. In addition to the statistical questions that the project is designed to answer, several additional results were obtained. Amongst these were maps of several sources with very weak core components relative to their extended jet emission, and evidence for a continuum of properties between bending jets and multiple hotspots in outer lobes. The former weakens arguments for relativistic bulk flow velocities in extended jets, and the latter helps to shed light on the nature of the interactions between radio sources and the generally invisible environment in which they are embedded.

The geodetic measurement program of the NASA Crustal Dynamics Project continues to produce accurate relative locations for many sites in North America (with a concentration in California and Alaska), the Pacific, and Europe. The accuracy of the velocity measurements improves as the number of observations and the span of time increases. The lengths of baselines between the participating stations now have uncertainties of less than 1 cm in many cases, and the length changes are known to be better than 1 millimeter per year for the longer-studied baselines. Additional improvements in accuracy are being sought by using phase delay as the observable instead of group delay for baselines up to a few hundred kilometers.

Of great importance to both the current and future VLBI programs has been the development by Haystack engineers of a high density recording system which provides a factor of 12 reduction in the number of tapes required for VLBI experiments. During the past year the production of large numbers of these systems has begun, and field installation at seven radio observatories has been completed. Most observatories equipped with Mark III terminals will have high-density recording capability by the end of 1987. Implementation of redesigned, upgraded Mark III correlators has also continued. The new correlator built for use at the Naval Observatory in Washington, D. C. and installed in 1986 has been expanded to process nine baselines simultaneously. The upgraded Mark IIIA correlator at Haystack is nearing completion and has been used for special experiments such as the satellite VLBI observations, summarized above, for which the unique capabilities of the new correlator are essential.

The Very Long Baseline Array (VLBA), being constructed under NSF sponsorship, consists of a 10-element array of 25-meter telescopes covering the continental USA, Hawaii, and Puerto Rico. Haystack is responsible for the development of the data acquisition systems of the VLBA; this includes design and construction of a prototype of the digitization and high-density recording sub-systems. The digitization electronics is presently being tested at the Very Large Array (VLA) site in Socorro, New Mexico. The high-density recording system has demonstrated that the VLBA system requirements can be achieved by recording and then playing back 5 Terabits of data on a single reel of tape. The prototype VLBA recorder will be delivered to the VLA for further testing, and, in late 1987, the system will be installed at the first VLBA telescope now being constructed at Pie Town, New Mexico. The VLBA, which is under the direction of the National Radio Astronomy Observatory, will provide VLBI scientists, including those at the Haystack Observatory, with a powerful high resolution astronomical instrument.
The MIT/Haystack Atmospheric Sciences Group which uses the Millstone Hill UHF radar for studies of the upper atmosphere has participated in an extensive World Day program involving monthly collaborative observations with radar facilities in Peru, Puerto Rico, Greenland, France and Scandinavia. Based on the data collected in these observations, an extensive set of empirical models have been developed which describe ionospheric characteristics and electric fields over a 30 degree span of latitude. The newly acquired 5 MW peak power capability of the Millstone UHF radar has been used to investigate the plasma composition in the ionosphere under solar cycle minimum and winter conditions. In order to facilitate collaborative experiments, other universities have installed instrumentation at Haystack during the past year in order to operate in conjunction with the Millstone radar. The University of Pittsburgh has located an automated optical airglow instrument and the University of Lowell has installed a digisonde to determine the peak electron density in the ionosphere.

Finally, in the past year, the Atmospheric Sciences Building at Haystack has been completed and has provided the group with significantly more space for students and staff. A greatly expanded summer student program has been realized using these new facilities.

JOSEPH E. SALAH
During the past year the Nuclear Reactor Laboratory (NRL) continued and strengthened its joint interdisciplinary activities with both MIT and non-MIT collaborators: eight academic departments and interdepartmental laboratories, the Charles Stark Draper Laboratory, and 31 other universities and nonprofit research institutions, such as teaching hospitals. These joint research or teaching and training activities cover a wide spectrum in the life and physical sciences and in engineering, including neutron scattering studies of condensed matter, reactor engineering, computer control of reactors, training in reactor operations, and radiochemistry and trace analysis applied to the health effects of energy use, nutrition, earth and planetary sciences, archeology, and nuclear medicine.

Especially noteworthy developments were the design, fabrication, and initial testing of major components for the multi-year in-core loop studies aimed at radiation dose reduction in light water power reactors and the award of a three-year grant for joint research with Tufts-New England Medical Center in the treatment of brain cancer utilizing the boron neutron capture method. These and other new or expanding programs are expected to more than compensate for the probable phasing out of most neutron beam tube research occasioned by the imminent retirement of Professor Clifford G. Shull.

NEUTRON BEAM TUBE RESEARCH

Ever since the start of operation of the MIT Research Reactor (MITR) in 1958, Professor Clifford G. Shull has provided inspirational leadership for a creative research program utilizing a variety of neutron spectrometers on several of the neutron beams of the MITR. For three decades this and other publications have reported the results of research by Professor Shull, his students and collaborators. Even as his neutron physics program phases down in the face of his retirement, his imaginative supervision of such research continues, another example of which is given below.

The existence of a new neutron Spin-Pendellösung resonance effect for neutrons diffracting in crystal has been confirmed with experiments in the Neutron Diffraction Laboratory. Within a diffracting crystal there occurs a periodic variation of energy flow direction as a function of penetration depth in the crystal (Pendellösung oscillation). When this is coupled with Larmor spin rotation of the neutron under resonant conditions, normal spin-orbit scattering contributions become greatly enhanced and measurable. This has been demonstrated for the case of Schwinger scattering (magnetic dipole/electric charge interaction) in silicon, which is unmeasurable by usual methods. The use of this resonance technique opens a new regime of sensitivity in searching for other suspected forms of spin-orbit interactions.

Professor Paul E. Sokol, Harvard Department of Physics, has expressed interest in the possible development of a neutron scattering program using the refurbished triple-axis spectrometer and other instruments. Initially it is planned to use existing instruments and then to develop a general purpose powder diffractometer as well as other instruments which would be suited to user needs.

RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey, Department of Earth, Atmospheric and Planetary Sciences, and research colleagues utilize the MITR for trace element analyses of geologic materials by neutron activation analysis (NAA). The activation analysis laboratory dedicated to geochemical studies is supervised by Professor Frey and Dr. Pillalamarri Ila and utilized by approximately 10 MIT graduate students, plus several visiting scientists from foreign countries and other US universities. Analyses of lavas from recently active volcanoes are emphasized with the objectives of identifying the mineralogy and composition of their source and the ascent paths of lava in the volcanic systems. During the past year, the Chilean volcano Villarrica, which erupted in 1984, was studied in collaborative effort with Professor R. Hickey, Florida International University, and Professors L. Lopez-Escobar and H. Moreno Roa, University of Chile.

During 1986-87 a major attempt to increase the utilization of NRL by making its neutron activation analysis facilities and expertise available to industry, other universities, private and governmental laboratories and hospitals in the area (as described in The MIT Report, May 1986) has been continued by Dr. Ilhan Olmez, who joined NRL two years ago. Research and/or service-oriented collaborations were established with several MIT research laboratories as well as with other educational and research institutions in addition to those established in previous years, including Tufts University, the University of Massachusetts, Cornell, Harvard, Northeastern University, and the State University of New York (SUNY), Albany. Commercial organizations that have utilized the NAA expertise of NRL during the past year have been Geo-Centers, Inc., Newton Upper Falls, Massachusetts; the Norton Company, Worcester, Massachusetts; Polaroid Corp., Cambridge, Massachusetts; Rochester Gas & Electric Corp., Rochester, New York; and the Computer Systems Division of Sperry Corp., St. Paul, Minnesota.
Within MIT, research support has been provided to several departments. Dr. Olmez has worked with Professor Adel F. Sarofim (Chemical Engineering), using multi-element NAA, to characterize the products of combustion with the ultimate goal of reducing environmental releases. NAA has been used to characterize samples of certain lignites and their pyrolysis products for Professor Jack B. Howard (also Chemical Engineering). The properties of certain polymers are improved by the addition of osmium, and NAA has been used to assay this element at nanogram levels for Dr. Osman S. Gebizlioglu (Mechanical Engineering) and Professor Robert E. Cohen (Chemical Engineering) to determine the amount taken up by the polymer. Improved NAA methodology has been developed to facilitate the assay of platinum compounds at picogram per gram levels \(10^{-12}\) in cancer-related DNA studies by Professor Stephen I. Lippard (Chemistry) on the effects of platinum.

Among his many projects, Dr. Olmez is working on the development of new techniques of medical diagnosis which are based on the determination of trace elements in different body fluids and tissues using NAA. Ongoing research carried out jointly with Rensselaer Polytechnic Institute has already shown significant variations of certain trace element concentrations between normal and cancerous tissues. He is also working with Massachusetts General Hospital (MGH) researchers on the trace element characterization of spinal cord fluid.

Dr. Olmez has been actively engaged in a number of environmental research projects. Recently financial support has been obtained from Northeast Utilities, Connecticut, to apply a novel method of detecting leakage from hazardous waste surface impoundments using NAA. It has been successfully demonstrated that a new approach, the use of enrichment factors, elemental signatures and ratios, is an effective way to identify the sources of groundwater contamination.

A powerful new data acquisition system was installed and put into operation this year. Based on a Microvax computer this system allows simultaneous acquisition of 32 spectra from high resolution solid state detectors. This capability permits NRL's trace analysis activities to grow with little constraint due to data reduction considerations.

A number of other research applications of NAA are summarized in a subsequent section, Reactor Irradiations and Services for Research Groups outside MIT.

NUCLEAR MEDICINE

Neutron capture therapy for cancers is, in principle, a uniquely attractive method of using radiation to destroy tumor cells without significant damage to healthy cells. Boron neutron capture therapy (BNCT) research and testing has a long history at the MITR, going back to the middle 1950s. Currently interest in this technique has greatly increased due to the apparent successes of Dr. Hiroshi Hatanaka of Japan, who has now used this therapy on approximately 100 people. Dr. Hatanaka became acquainted with BNCT when he worked at MIT during the early trials. At the present time Professor Otto K. Harling has arranged a collaboration with several senior staff from the Tufts-New England Medical Center. A proposal leading to clinical trials in three years has been developed and has received funding from the United States Department of Energy (DOE). The $1.2M grant will be enhanced by the support provided through MIT and the Tufts-New England Medical Center.

The MIT Reactor also supports nuclear medicine programs conducted by several hospital and radiopharmaceutical groups outside MIT. A summary of these activities is provided in a following section.

RADIATION HEALTH PHYSICS

The NRL supports a new subdiscipline in the Nuclear Engineering Department (NED), Radiation Health Physics, by providing relevant research opportunities and a specially designed laboratory/demonstration course. This course, 22.09/22.59 Principles of Nuclear Radiation Measurement and Protection, has been reorganized so that it is appropriate for all students in NED. This restructuring has also permitted reduction of NED courses by one course. The Radiation Health Physics program is under the direction of Professor Harling. The program is designed to produce graduates who are well educated in nuclear engineering fundamentals as well as in the basics of radiation measurement, management, and protection. Basing this activity at the NRL is particularly appropriate since the MITR provides excellent opportunities to learn many aspects of this subfield in a realistic environment. Support for graduate students has been obtained from the Institute of Nuclear Power Operations and from several nuclear utilities.

COMPUTER CONTROL OF REACTORS

Professor David D. Lanning, Nuclear Engineering Department, and Dr. John A. Bernard of the NRL continued studies on the closed-loop, digital control of nuclear reactors during both steady-state and transient operation. Assistance was received from Professors Allan F. Henry and John E. Meyer (NED) and from Dr. John H. Hopps, Jr., of Charles Stark Draper Laboratory. A general set of control principles, based on reactivity constraints and intended for nonlinear conditions, has been deduced and experimentally demonstrated on the MIT Reactor. This approach is unique in that it is based on the general equations of reactor
dynamics rather than measurements of specific response characteristics. This work is currently supported by the United States Department of Energy, by the Sandia National Laboratories (SNL), and by the National Science Foundation (NSF). It has resulted in nine publications during the past year. The 'reactivity constraint approach' has been licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MW MIT Research Reactor. Closed-loop control experiments can be performed without a priori restrictions on the associated reactivity. The significance of this license approval is that 1) no other research reactor in the United States has such a broad approval for closed-loop control and 2) a precedent has been established for our approach regarding such control. This gives the reactivity constraint concept an enormous lead over competing ideas in the United States. A major accomplishment of the project during the past year has been the development and experimental demonstration of closed-form control laws that permit adjustments of reactor power to be accomplished in minimum time. These laws will be used for the control of reactor-powered spacecraft. Research in progress includes 1) an experimental study of the value of providing reactor operators with predictive information, 2) redesign of the mechanical interface of the MIT Research Reactor's control system, and 3) the extension of the non-linear closed-loop control techniques to the operation of large reactors that are characterized by spatial dynamics. There are currently one M.S. and four Ph.D. theses in progress on topics related to this research. Demonstrations of the technology are available by appointment.

DOSE REDUCTION IN NUCLEAR POWER REACTORS

A major interdisciplinary and interdepartmental research program designed to develop radiation dose reduction technology for the nuclear power industry has been initiated during the past year with the Empire State Electric Energy Research Corporation (ESEERCO) and the Electric Power Research Institute (EPRI). Funding at the level of $2.5 million for four years is now available to support the project. Radiation fields in the primary cooling system of today's light water reactors are undesirable from a health viewpoint and have a significant negative impact on plant capacity factors by impeding maintenance tasks. The principal goal of the project is to reduce the radiation fields to which workers are exposed. Studies of how these fields are built up and methods for minimizing them will be conducted with the aid of small-scale coolant circulation loops installed in the core of the MIT Reactor, designed to simulate (in separate loops) conditions that exist both in pressurized-water reactors and in boiling-water reactors. The formation, transport and deposition of corrosion products in the coolant will be characterized, and tests will be carried out to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Harling and Professor Michael J. Driscoll, Department of Nuclear Engineering. Others already participating are Dr. Gordon Kohse and Dr. Ilhan Olmez of NRL, members of the MIT Reactor staff, Professors Ronald G. Ballinger, Asashi Kitamoto, and David D. Lanning of NED, Professor Ronald M. Latanision of the Department of Materials Science and Engineering, Dr. William Lindsay, an expert consultant in the field of reactor coolant corrosion studies, and a growing number of MIT students from the departments mentioned above. Three utilities - Public Service Electric & Gas, Duke Power, and Boston Edison - have provided additional financial support. These projects will utilize the MIT reactor directly and provide much needed support for experimental research in nuclear engineering. It is expected that two to four graduate students will continue to be involved in this project.

REACTOR IRRADIATIONS AND SERVICES FOR RESEARCH GROUPS OUTSIDE MIT

In nuclear medicine the development and/or continuing production of radioisotopes for use by researchers at hospitals and other universities included: 1) production of Au-198 seeds for Dr. Philip Cobb of the New England Deaconess Hospital for use there and in other area hospitals for cancer therapy, 2) research activities by Professor Webster S. S. Lee's group at the University of Utah Radiobiology Laboratory using solid state fission fragment track detectors to study the distribution and transport of plutonium in animal models, 3) production of Pt-197 and Os-193 Mössbauer sources for the Chemistry Department at Northeastern University to study the chemistry and structure of gold compounds, particularly those exhibiting anti-arthritic and anti-tumor activity, 4) production of Dy-165 for Dr. Clement B. Sledge of Brigham and Women's Hospital for research studies in the treatment of arthritis, and for Cadema Medical Products, Inc., Middletown, New York, and Gamma Diagnostic Laboratories in Attleboro Falls, Massachusetts, for development of the commercial Dy-165 radiopharmaceutical, 5) use of the reactor by Cadema Medical Products, Inc., to produce holmium-166 for a feasibility study since this nuclide appears to possess superior properties for radiation synovectomy of rheumatoid arthritis; 6) assistance to Cadema Medical Products, Inc., in preclinical trials of radiation synovectomy with both Dy-165 and Ho-166; and 7) analysis of tissue samples by NAA for Professor I. L. Fries, Chemistry Department, Rensselaer Polytechnic Institute, in a study of the relationship between cancer incidence in rats and the trace element abundances in rat spleen, liver, and other organs.

In a number of other areas, also, reactor irradiations and services were performed for research groups outside MIT. Some of these represent new activities, while a number are continuations of previous research: 1) Dr. Robert Tiernan of GTE Sylvania, Inc., continued use of the reactor to study the effect of sodium diffusion through aluminum oxide on the performance of sodium vapor lamps; 2) Dr. Frank Pink from the same laboratory irradiated ceramic materials to determine the uranium content with solid state neutron track detectors and the thorium and other impurities by NAA; 3) silicon diodes for power systems requiring high
temperatures and high radiation tolerances were irradiated in a fission neutron spectrum for an irradiation effects study being conducted by Professor W. T. Joyner in the Physics Department at Hampden-Sidney College; 4) additional samples of aluminum oxide were irradiated for Dr. Forrest C. Burns at the US Army Materials Technology Laboratory, Watertown, Massachusetts, to determine their elemental content by neutron activation analysis. Additional NAA services, including many for research groups outside MIT, were reported in an earlier section, Radiochemistry and Trace Analysis.

Whereas most of the above outside users pay for irradiation services at the reactor, educational institutions needing such services for their own academic or research purposes are assisted in this regard by the USDOE through its "Reactor Sharing Program." Grants are made to universities owning reactors to reimburse them for the costs of providing irradiation services and facilities to other institutions (including teaching hospitals). Under this program, nearly 300 students and 50 faculty and staff from 28 other educational institutions benefited from visits to and use of the MITR during the past year. These figures do not include those reported in a following paragraph for the high school science teachers program. Popularity of the sharing program continues to grow, and a 40 percent increase in grant funds has been awarded to MIT for the coming year.

Research utilization of the MITR by other institutions under the Reactor Sharing Program during the past year have included: 1) Professors J. Christopher Hepburn and Rudolph Hon used the MITR to activate geological specimens and standards for the NAA of Rare Earth and other trace elements in studies of the geological development of the northeastern US; 2) neutron irradiation of NiP magnet glass alloy discs was used by Professor Abdul Ibrahim, Boston University, for non-destructive analysis by NAA methods; 3) analyses were carried out for Professor Tadgh Begley, Chemistry Department, Cornell University, to identify metals and other trace elements in a study of the coupling mechanisms of certain enzymes; 4) clay layer samples from the Cretaceous/Tertiary Boundary, Cuddia, Italy, that were provided by Professor Charles Officer, Earth Sciences Department, Dartmouth College, were assayed for trace Platinum Group metals by NAA to confirm theories regarding extinction of the dinosaurs by volcanic activity at the end of the Cretaceous Period; 5) samples of ancient ice from the South Pole were analyzed by NAA for Dr. Edward Fireman, Harvard-Smithsonian Astrophysical Observatory, in preliminary studies to learn whether or not we can determine natural or anthropogenic contamination of ice at those very low concentrations; 6) the triple-axis spectrometer on the 6SH4 port was used by Professor Paul E. Sokol, Physics Department, Harvard University, in preliminary studies of the high energy inelastic neutron scattering from hydrogen adsorbed on grafoil; 7) plant seeds for selected Matignon High School students participating in science fair projects were subjected to gamma irradiation under the supervision of Judith A. Howley, Chairperson, Science Department; 8) rock samples were irradiated for Dr. Louis J. Caruso, Geology Department, Stanford University, as part of a study which involves induced fission track techniques to date the sealing of natural fractures in rocks; 9) calcium and terbium at nanogram/gram levels in biological material were assayed by NAA methods for Professor Henry G. Mautner, Biochemistry and Pharmacology Department, Tufts University, in support of a study of calcium binding sites in membranes; 10) archeological samples were analyzed by NAA for Professor Alex Kaczynarszczyk, Chemistry Department, Tufts University, as an aid in determining the original sources of materials used in the samples; 11) mandibles from leaf-eating insects such as the tobacco hornworm have been assayed by zinc and other heavy metal ions using NAA for Professor M. Sugumaran, Biology Department, University of Massachusetts, Boston, in support of an investigation of the reasons for abnormalities in such creatures; 12) NAA was carried out for Professor David A. Reckhow, Civil Engineering, University of Massachusetts, Amherst, to determine the chlorine and bromine content of extracted water samples; 13) preliminary analyses were made by NAA methods for Professor R. A. Wobus, Geology Department, Williams College, to assay rare earth elements in igneous rock samples from Colorado.

For education of the general public and students at all levels in local and other New England schools, the reactor staff provides lectures and tours periodically throughout the year. Several local universities incorporated reactor visits and experiments into their regular course curricula, as follows: 1) Northeastern University, Mechanical Engineering Department, Nuclear Engineering I, Course 02.236, 36 students, 15 visits; 2) Northeastern University, Physics Department, CoursePHY 1555, 8 students, 5 visits; 3) University of Massachusetts, Harbor Campus, Department of Physics, Physics 697B, 31 students, 5 visits.

Following successful trials in the previous year, the USDOE separately funded an expanded educational program to familiarize high school science teachers with the scientific, engineering, and medical uses of nuclear research reactors and to involve the teachers in typical applications and experiments, with a special lecture and demonstration by the MIT Radiation Protection Office. Seven classes (two four-hour days each) were held with very enthusiastic response from the 84 teachers who attended.

MIT RESEARCH REACTOR

The MIT Reactor completed its 28th year of operation, its 12th since the 1974-75 shutdown for upgrading and overhaul. During the past year it continued its usual Monday through Friday operating schedule at the design power level of 5 MW, averaging 80.1 hours per week at full power, holidays and scheduled maintenance periods included. Energy output for the MLTR-II, as the upgraded reactor is now called, totaled 220,624 megawatt-hours at June 30, 1987. The MITR-I generated 250, 445 MWH in the sixteen years from 1958 to 1974.
To summarize briefly the reactor utilization described in more detail above, it was well utilized during the year, although still more experiments and irradiations can be accommodated due to the number and versatility of its many facilities. The reactor, as an integrated whole, continues to be used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. A pressurized loop for a major new interdepartmental project on dose reduction for power reactors is close to installation in the reactor. The production of dysprosium-165 is being increased for distribution to New York as well as Boston for arthritis knee therapy. Utilization of the neutron beam ports for neutron diffraction experiments decreased substantially, but the triple-axis spectrometer, now refurbished to provide digital computer control of inelastic scattering experiments, may find a user. The number of specimen irradiations was over 1500. Theses and publications on research supported by the reactor are running at about 20 and 60 per year, respectively.

DOE continues as the supplier of fuel to university research and training reactors. Babcock and Wilcox (B&W), Lynchburg, Virginia, is the fabricator and is part way through the production of another batch of fuel for the MITR-II.

In 1985-86 a portion of the reactor costs were offset by a first-time grant from DOE in direct support of operation of the MITR-II. During the past year, in connection with the generic question of such support for university reactors, the National Academy of Sciences-National Research Council (NAS-NRC) has been conducting a study to assess the value and costs of university research reactors and whether the Federal Government provides adequate financial assistance for their operation and the research programs that they support. Federal funding falls far short of the assistance provided by DOE and NSF to a number of US universities for operation and utilization of particle accelerators; it is also much less than several European governments provide for support of their university class research reactors. In connection with this study, NRL has assisted NAS-NRC to accumulate detailed information regarding research reactor accomplishments. A report favorable to the needs of university research reactors is expected to be completed before the fall of 1987 by the NAS-NRC committee.

OTTO K. HARLING
The Operations Research Center, established in 1953 as an interdepartmental graduate degree program, completed its 34th year of continuous operation. This year has been one of renewed energy and initiative at the ORC, in part as a direct result of the review of operations research at MIT, conducted by a committee commissioned last year by the Provost's office. The result has been a greater degree of faculty participation and the pursuit of several educational and research initiatives.

Much about the academic and research program remained the same, and, indeed, the Review Committee found many aspects of the program to be of excellent quality. The Committee recommended that the ORC preserve and strengthen its education program, and this year the faculty have endeavored to address some areas of weakness. The Committee's other major recommendation was to establish a center at MIT devoted to the decision sciences, and ORC faculty rallied behind this impetus.

The Operations Research Center had two new codirectors this year - Thomas L. Magnanti, George Eastman Professor of Management Science and Amedeo R. Odoni, Professor of Aeronautics and Astronautics and of Civil Engineering. The Center also added two new affiliated faculty members, and now draws its 27 affiliated faculty from the Sloan School of Management, Electrical Engineering and Computer Science, Civil Engineering, Mathematics, Aeronautics and Astronautics, Ocean Engineering, Urban Studies and Planning, and Nuclear Engineering. Approximately 46 students were enrolled in the master's and doctoral degree programs.

Faculty and students at the ORC were engaged in a broad range of activities during the past year. The Center's research addressed numerous topics in mathematical programming, manufacturing systems, transportation and logistics, public sector applications, applied queueing research, and competitive strategy. This report briefly discusses each of these areas and highlights the ORC's educational activities.

RESEARCH ACTIVITIES

Mathematical Programming and Combinatorial Optimization

Mathematical programming and combinatorial optimization are fields concerned with methods for creating and solving constrained optimization problems. ORC faculty and students continue to make important contributions to these fields.

Ongoing research projects covered both well-established fields of inquiry and emerging topics. Examples in the former category include work on parametric linear programming and anti-cycling pivoting rules and on fixed point theory. The second category includes several ongoing projects. One is concerned with the development of modeling languages for integer programming that would aid a user in developing integer programming models. A second examines projective transformation methods for linear programming, an approach stimulated by the recent pioneering work of N. Karmarkar. Other projects deal with the matroid parity problem, greedoids which are combinatorial structures that are intimately connected with simple one-pass approaches to combinatorial problems known as "greedy algorithms," and cluster analysis, an area of work that is important in statistical analysis.

In addition, the faculty have studied parallel algorithms and approximation methods for combinatorial optimization problems, and distributed algorithms for nonlinear optimization. They have also studied promising new methods in integer programming as applied to problems in facility location, production planning, and machine scheduling.

Network Optimization

A number of recent developments have stimulated renewed interest in some of the classical and fundamental problems in network optimization, such as the shortest path problem, the maximum flow problem, and the minimum cost flow problem. Not only are these problems important in their own right, but also they are used as essential building blocks in solving other network problems. During the last year, our faculty made major strides toward developing algorithms for each of these three problems that may well prove to be the fastest that have been developed to date.

The faculty have also continued to work on problems of network synthesis. These investigations have led to new methods for several very large-scale applications.
In the area of network routing, the faculty and students made two noteworthy contributions: the analysis of a family of very applicable routing problems with "time-window" constraints, i.e., with upper and lower limits on when a particular point can be visited; and a set of interesting and occasionally counter-intuitive results on the probabilistic traveling salesman problem, which combines combinatorial and stochastic considerations.

Facility Location Theory

Several faculty and students worked on various types of facility location problems that arise in such contexts as logistics planning, product positioning for marketing, and urban emergency services. One result was a new algorithm, based on ideas from complementary pivot theory, for solving a variety of single-facility location problems. Two other projects dealt with facility location in a stochastic environment characterized by demands generated at random times, uncertain travel times, and the presence of congestion due to the finite capacity of the facilities.

Manufacturing Systems

International competition, changes in technology, and concerns about low productivity have caused managers to seek fresh approaches for controlling manufacturing systems. As a result, new opportunities have arisen for applying operations research models and methods to support manufacturing decision making. ORC faculty and students were involved in several projects concerned with production scheduling, the design and expansion of flexible manufacturing systems, job shop scheduling, manufacturing learning, workforce flexibility, and quality control. Techniques employed included queuing networks, mathematical programming, heuristics, and Monte Carlo simulation. The research was supported by grants from C. S. Draper Laboratory, IBM, MA/COM, Coopers and Lybrand, and Cullinet Software. This topic represents one of the fastest growing areas of research at the ORC and is attracting increasing numbers of students and faculty.

Transportation and Logistics

Under sponsorship from the GTW Railroad, North American Van Lines, and Burlington Northern Railroad, faculty and staff worked on research projects on locomotive scheduling, truck routing, and the logistics of freight movement on a network-wide basis. The principal methodological tools in this research are those of large-scale mathematical optimization. However, the standard techniques available must be modified in important respects if they are to be applied successfully to the types of problems encountered in practice, at both the tactical and strategic levels of planning.

One ORC project, sponsored by the Office of Naval Research, addressed issues of routing and scheduling of a large fleet of cargo ships during times of national emergency. This problem is enormously complex because of the huge number of relevant variables and operational constraints. A major product of this research is an interactive algorithm to assist schedulers with their numerous tasks. The Military Sealift Command decided to implement this approach, a step which will be undertaken during the coming year.

Air transportation is another area of interest to ORC faculty. Under FAA sponsorship, faculty and staff developed mathematical models to help air traffic control planners to estimate controller workloads at specific points on the enroute ATC system. Under the same project, a comprehensive look at the airline safety record of the last eight years not only revealed very significant problems in aviation safety on a worldwide scale, but also suggested causes of concern for the future, such as a potential negative impact of airline deregulation. Yet another area of activity in this general subject is the development of time-dependent queuing models to estimate airport delays under a wide range of conditions.

Near the end of the year, the ORC undertook a major initiative in the area of industrial logistics. This effort is aimed at bringing together Institute-wide resources and expertise in the fields of manufacturing, logistics, transportation, information processing, and operations research so that collective research efforts can become more effective and visible.

Public Sector Applications

ORC faculty and students developed operations research applications in the public sector in the areas of criminal justice and emergency urban services. Under a grant from the National Institute of Justice, work continued on developing algorithms for computer-aided dispatch systems for police departments. These systems help "911" call-takers and police radio dispatchers to receive and quickly process calls for police service from the public.

Another project attempts, through the use of statistics and age-dependent probabilistic models, to explore the relationship between crime rates and factors such as demographics, deterrence, and prison populations.
Applied Research in Queueing

Research continued on a three-year grant from the National Science Foundation on analysis of queueing delays and queueing system environments. This research is predicated on the hypothesis that the customer’s actual and/or perceived cost of participating in a queueing-line service system are (1) a nonlinear function of the queueing delay and (2) multiattributed. The other attributes, in addition to queueing delay, reflect the customer's attitudes toward the queueing environment and the extent to which the system design or operation leads to “social injustice”. The new theoretical and empirical results developed, clearly describe customer behavior more accurately than conventional models. This topic is another particularly promising area of research.

EDUCATIONAL PROGRAMS AND ACTIVITIES

The Operations Research Center offers two interdepartmental graduate degree programs, one leading to a PhD degree in Operations Research and the second leading to a master's degree. During 1986-87, these programs enrolled 46 students - 26 PhD candidates and 20 SM candidates. Eight master's degrees and four PhD degrees in operations research were conferred during 1986-87.

Students in the Operations Research Center represent a variety of backgrounds and countries. More than 50 percent of ORC students were from foreign countries; 30 percent of the students were women. ORC students have attained considerable scholastic achievement, as evidenced by the number of fellowships and scholarships they hold; several students held scholarships or fellowships from their respective countries and from the Charles Stark Draper Laboratory. Other students have received departmental teaching awards.

In accordance with some of the recommendations of the Committee to Review Operations Research at MIT, which was formed in 1985-86, ORC faculty undertook several initiatives. The faculty formed a subcommittee to address the question of restructuring the master's degree program in a way that focuses the curriculum on concentration areas, e.g., transportation and logistics, manufacturing, operations management, and so forth. The subcommittee discussed the fundamental issues connected with the proposed changes and will make recommendations to the ORC faculty in the next academic year.

Another recommendation of the Review Committee concerned the lack of a coherent structure in the stochastic systems sequence of subjects available to ORC students. The faculty decided to add a course in discrete event optimization to the curriculum. Further, they discussed establishing a new course on modelling of stochastic systems and suggested an approach for upgrading the statistics requirement for ORC doctoral students.

As part of an outreach to increase student awareness of operations research, ORC faculty gained approval from the School of Engineering to introduce operations research subjects in the undergraduate curriculum. Two subjects have been approved for the 1987-88 academic year: Stochastic Models, Reliability, and Simulation of Large-Scale Systems; and Engineering Systems Optimization will be offered as school-wide electives. The School of Engineering is also considering the addition of two other school-wide electives, in the areas of decision analysis and data communications.

The Review Committee also recommended an expansion of the scope of decision sciences at MIT, and ORC faculty actively pursued this initiative. The Committee’s major recommendation is the proposal for a new organizational unit, called the Decision Sciences Center, which would bring together the Operations Research Center, the Statistics Center, and a new computational laboratory.

The Operations Research Center regularly offers professional courses during the Summer Session. In the summer of 1986, it offered three such programs: “Decision Analysis: Basic Concepts and Applications,” “Decision Analysis with Multiple Objectives: Concepts and Applications,” and “Operations Management in the Service Industries.”

The ORC Seminar Series was privileged to have many distinguished speakers from business and industry as well as from academia this year. The operations research professionals who made presentations at the Center’s long-standing external seminar series included Clyde Monma from Bell Communications Research, Jan Karel Lenstra, Center for Mathematics and Computer Science, Amsterdam, Leslie E. Trotter, Cornell University, Willard Zangwill, University of Chicago, and Richard Cottle, Stanford University.

THOMAS L. MAGNANTI
AMEDEO R. ODONI
Codirectors
During the past year, technical progress has been made in all Plasma Fusion Center (PFC) research programs. The Plasma Fusion Center is recognized as one of the leading university research laboratories in the physics and engineering aspects of magnetic confinement fusion. Its research programs have produced significant results on four fronts: (a) the basic physics of high-temperature plasmas (plasma theory, RF heating, free electron lasers, development of advanced diagnostics and small-scale experiments on the Versator tokamak and Constance mirror devices), (b) major confinement results on the Alcator C tokamak, including pioneering investigations of the stability, heating, and confinement properties of plasmas at high densities, temperatures and magnetic fields, (c) operation of the medium-scale TARA tandem mirror, an axisymmetric confinement configuration with inboard thermal barriers, and (d) a broad program of fusion technology and engineering development that addresses problems in several critical subsystem areas (e.g., magnet systems, superconducting materials development, environmental and safety studies, advanced millimeter wave source development, and system studies of fusion reactor design, operation, and technology requirements). The Plasma Fusion Center technical programs are supported principally by the Department of Energy's Office of Fusion Energy. During the past year, the funding level has been approximately $25 million. There are approximately 300 personnel associated with PFC research activities. These include: 29 faculty and senior academic staff, 65 graduate students and 15 undergraduate students, with participating faculty and students from Aeronautics and Astronautics, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics; 92 research scientists and engineers and 25 visiting scientists; 37 technical support personnel; and 36 administrative and support staff.

ALCATOR CONFINEMENT EXPERIMENTS

The primary objective of the Alcator experimental program, headed by Ronald Parker, is to develop the basic physics understanding of the stability, transport, and radiation properties of high-temperature tokamak plasmas at near-reactor conditions and to develop radio-frequency (RF) methods for heating and driving currents in plasmas at thermonuclear temperatures. The Alcator C facility, which began operation in 1978, was shut down in February, 1987, and the tokamak core has been relocated to Lawrence Livermore National Laboratory (LLNL), where experiments will be carried out to investigate electron cyclotron resonance heating (ECRH) using a high-power free electron laser (FEL). Professors Ronald Parker and Bruno Coppi have been principal investigators of the overall Alcator C program. Construction has begun of a follow-on device to Alcator C, called Alcator C-MOD, which will be located in the east wing of the Nabisco Laboratory. Alcator C-MOD will provide valuable technical information for the operation of a high-field tokamak ignition experiment, and contribute to advanced tokamak concepts in the areas of stability, auxiliary heating, particle and profile control, and non-inductive current-drive techniques. The pioneering Alcator A tokamak, which was retired from operation in 1979, has been donated to the MIT Historical Collection.

The main Alcator C experimental areas have included: device operations (David Gwinn); confinement studies (Stephen Wolfe); plasma-wall interactions (Earl Marmar); radio-frequency heating (Miklos Porkolab); data acquisition and computations (Martin Greenwald); and toroidal analysis (Dieter Sigmar). David Gwinn is manager of the Alcator C-MOD construction project, and the physics team responsible for developing the Alcator C-MOD experimental program is headed by Stephen Wolfe.

RF Heating and Current-Drive Experiments on Alcator C: Ion cyclotron heating (ICH) experiments have been carried out using both fast-wave launching and ion-Bernstein-wave launching in the Alcator C tokamak for densities in the range \(0.7 \times 10^{14} \text{ cm}^{-3} \leq n_e \leq 5 \times 10^{15} \text{ cm}^{-3}\), and toroidal magnetic fields between 5 and 12 Tesla. Fast-wave heating experiments resulted in ion temperature increases of \(\Delta T_i \leq 500 \text{ eV}\) at input powers of \(P \leq 400 \text{ kW}\) at the fundamental harmonic (\(\omega = \omega_{CH}\)) of the hydrogen minority species in a deuterium majority plasma. Two new antennae with improved wavenumber spectra have been fabricated to improve the heating efficiency above that obtained in 1985. The experiments have been successful in that good heating efficiency has been demonstrated at low densities (\(n_e \approx 1 \times 10^{14} \text{ cm}^{-3}\)), similar to other tokamak experiments. However, as the density was raised, the heating became less efficient relative to ohmic heating. In addition, at high densities (\(n_e \approx 5 \times 10^{15} \text{ cm}^{-3}\)), only minimal heating was observed. The understanding of these results is important in view of the ion cyclotron heating experiments planned on Alcator C-MOD and the Compact Ignition Tokamak (CIT).

Ion-Bernstein-wave (IBW) heating has been tested both at a majority-species odd-harmonic resonance (\(\omega / \omega_{CH} = 3/2\)) and for minority absorption (\(\omega / \omega_{CD} = 3\), \(\omega / \omega_{CD} = 5/2\)) in a hydrogen majority plasma. During ion-Bernstein-wave injection, an increase in the bulk ion temperature and an increase in the particle confinement time are observed. Strong ion heating is observed in the density range \(0.7 \times 10^{14} \text{ cm}^{-3}\), where \(T_i\)
The Mirror Confinement Experiments Division, headed by Richard S. Post, is involved in the operation of the medium-scale TARA tandem mirror research facility. This experimental facility, with the full complement of heating systems and diagnostics, was brought into operation in April, 1985. Initial experiments began in 1984. TARA represents a major activity within the national fusion program. The primary objectives of TARA experimental operation during the past year included: MHD stability analysis; development of a new central-cell MHD stabilization scheme; and endless plugging. These experiments will enable an
evaluation of the potential of tandem mirrors to operate in a purely axisymmetric configuration, either for confinement or neutron-source applications. The main areas of activity include: Division management (John Tarrh); TARA operations and power engineering (Marcel Gaudreau); experimental and RF systems (Stephen Golovato); and computations and advanced concepts (Jay Kesner).

TARA Tandem Mirror Experiment: The TARA device is currently in its third year of operation. Experiments were resumed in April, 1985, after a six-month period during which the TARA device and systems were significantly upgraded. In addition to the installation of a 6 MW neutral beam system, which essentially completed the major part of TARA construction, new diagnostics and heating and fueling systems were added to the central cell and axisymmetric plugs. Experiments with the new TARA configuration indicate improved plasma performance in the central cell and plug parameters appropriate for successful neutral-beam injection experiments.

The TARA tandem mirror consists of a 10 m solenoidal cell bounded by axisymmetric confining plugs and outboard minimum-B MHD anchors. The configuration was designed to minimize radial particle transport and to evaluate purely axisymmetric configurations. To this end, a central-cell magnetic divertor was installed during the past year for MHD stabilization without the use of the outboard anchors. The major physics objectives of TARA are to investigate plasma stability, central-cell radial transport, and the formation of enhanced potential barriers in the plugs to limit the axial loss of ions and electrons.

Based on earlier data, the central-cell heating and fueling systems were redesigned to reduce hot ion losses due to charge-exchange recombination with cold neutral hydrogen and to limit the flux of neutral gas into the plug, where it would be expected to interfere with the neutral-beam buildup of the plasma. Greatly improved gas utilization has been achieved with the new fueling system, and the neutral gas pressure in the plug is now sufficiently low for neutral-beam operation. TARA central-cell plasma parameters have improved continually during the past year. With 400 kW of RF power in the ion cyclotron range of frequencies (ICRF), the ion temperature is approximately 800 eV, the density is approximately $4 \times 10^{12} \text{cm}^{-3}$, and the plasma beta (ratio of plasma pressure to magnetic pressure) is approximately 2%. The energy confinement time has doubled in recent operation.

By employing a new central-cell start-up technique and by installing the magnetic divertor for added MHD stabilization, a new series of plugging experiments has been carried out. These experiments are aimed at resolving whether energy confinement can be improved through the reduction in axial plasma endloss via electrostatic fields. The plugging field is generated using low-frequency RF fields or high-frequency microwave fields. To date, plugging has reduced the endloss typically by 50%. About 50% of this endloss power flows back into the confinement region and the remainder flows out radially. Reducing the radial transport and further endloss reduction are required before substantial improvement in energy confinement can be achieved.

Computations and Advanced Concepts: The TARA research program has a combined theoretical and experimental effort that permits a close collaboration between experiment, theory, and computations. Areas of emphasis include low-frequency stability (trapped-particle and MHD theory), microstability, and RF heating theory. Recent theoretical studies include hot-electron interchange modes, equilibrium potential formation in the presence of hot-electron populations, and loss-cone instabilities.

Alternate applications of mirror-based configurations, such as neutron-source applications to component and materials testing, have also been explored. In addition, investigations of novel magnetic geometries and confinement approaches have continued.

Future Plans: The combination of declining national budgets for fusion and the increased commitment to large tokamaks, such as the Compact Ignition Tokamak (CIT) and the International Tokamak Experimental Reactor (ITER), has led to a decision by the Department of Energy to terminate the national mirror program. There will be a technical review of TARA in August, 1987, which could lead to a modification of DOE's present plan to terminate TARA operation later this year. In its projections for FY88, the Department of Energy has provided funds for a major part of the TARA group to begin research in the toroidal area.

APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the Plasma Fusion Center Applied Plasma Physics Research Division, headed by Ronald Davidson, is to develop the basic experimental and theoretical understanding of plasma heating and confinement properties. Present applied plasma physics research activities include: experimental research on the Versator II tokamak (Miklos Porkolab and Stan Luckhardt); experimental research on the Constance B mirror device (Richard Post and Donna Smatlak); fusion theory and computations (Abraham Bers, Bruno Coppi, Ronald Davidson, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, and Dieter Sigmar); plasma diagnostics and laser development (Daniel Cohn and Paul Woskoboinikow); and space plasma theoretical research (Kim Molvig).

The progress made during the past year in selected applied plasma physics research areas is summarized below.
Versator II is a medium-sized research tokamak (major radius = 40.5 cm, minor radius = 13 cm, toroidal field = 15 kG) with primary emphasis on basic investigations of RF plasma heating and current drive. During the past year, construction of a major new 100 kW, 35 GHz electron cyclotron resonance heating (ECRH) experiment was completed. These experiments will test plasma heating and current-drive processes using a combination of RF power near the lower hybrid frequency and the electron cyclotron frequency. Extensive theoretical predictions from groups in the U.S. and Europe will be tested in this experiment. A second, combined current-drive experiment is in the construction stage, which will use 800 MHz fast lower hybrid waves in conjunction with 2.45 GHz slow waves. Again, the combination of the two types of waves will provide a test of the theory of RF current drive. To launch the fast wave in Versator II, a dielectrically-loaded (TiO₂, ε = 80), phased-waveguide-array structure has been designed and is being fabricated by industry. This experiment is expected to become operational later in 1987.

Constance B is a quadrupole mirror device of moderate size in which high-beta, hot-electron plasmas are created using electron cyclotron resonance heating (ECRH). The major objective of the Constance program is to contribute to the basic physics understanding of the equilibrium, stability, and heating of hot electron plasmas. Investigations of ion transport in the quadrupole geometry and high-Z ion confinement are also fundamental parts of the Constance B program. This research is carried out by five graduate students.

The increasingly wide use of ECRH in tokamaks and mirrors necessitates the study of the basic physics of the absorption and heating processes. Controlled experiments characterized by pure extraordinary-mode or ordinary-mode illumination, the absence of cavity fields, and a well-defined kᵢl spectrum have been carried out on Constance during the past year. Comparison of these results with Fokker-Planck calculations are in progress.

Recent proposals to use hot electrons for stabilization of tokamaks in order to access the second-stability regime are predicated on ideal MHD theory. The hot-electron equilibria obtained in Constance are observed to be macroscopically stable for fractions of a second even though, according to ideal MHD theory, the plasma is expected to be unstable within a few microseconds. An extensive experimental characterization of this equilibrium has been carried out, and detailed theoretical calculations will be done in order to understand this equilibrium and its impact on the use of a hot-electron population in tokamak plasmas.

As part of an effort to broaden the scope of the program, the confinement of impurity ions in Constance is being studied in order to advance the physics understanding of electron cyclotron resonance (ECR) ion sources. ECR ion sources are widely used in accelerators for basic nuclear physics research but are not well understood. High-Z ion confinement is the key physics issue that needs to be addressed. Methods of improving ECR ion source operation by selectively enhancing the production of particular charge states using ion cyclotron resonance heating (ICRH) will also be studied.

In plasma theory and computations there has been substantial technical progress in several areas of research. The theoretical studies include: (a) electron heating and transport by ion cyclotron waves in tokamak plasmas; (b) strong absorption in mode conversion for ion heating; (c) efficiency and transport in lower hybrid current drive; (d) investigations of two-dimensional kinetic plasma turbulence; (e) theory of MHD clumps; (f) axisymmetric, kink and ballooning-mode stability of advanced-shaped tokamak plasmas; (g) theory and implementation of magnetic probe diagnostics on non-circular tokamaks; (h) effect of energetic trapped alpha particles on ballooning modes; (i) theory of alpha-particle effects in ignited tokamak plasmas; (j) transport theory of impurities in Alcator C and the effect on sawtooth oscillations; (k) stabilization of the m = 1 MHD mode by means of a magnetic limiter; (l) study of advanced toroidal configurations such as the DRAKON; (m) theory of free electron lasers including the development of advanced concepts, studies of harmonic generation, and nonlinear models for saturation and efficiency enhancement; and (n) theoretical studies of the nonlinear evolution of the electron whistler instability in magnetospheric plasmas.

FUSION TECHNOLOGY AND ENGINEERING

The Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides critical engineering analysis for advanced design projects, and develops advanced superconducting and high-field copper magnet technology for the national fusion program. The areas of research during 1986-87 include: engineering design support for the recently authorized Alcator C-MOD tokamak (Bruce Montgomery); studies of advanced poloidal field magnets for the Compact Ignition Tokamak (Richard Thome); studies of advanced magnets for the International Tokamak Experimental Reactor program (Joel Schultz); concept development for improved magnetic divertors for tokamaks and next-generation test reactors (Ted Yang); development of internally-cooled, cabled superconductors for use in advanced fusion devices (Mitchell Hoenig); basic research on high-field, ductile superconductors (Simon Foner); and advanced magnet and conductor design in support of MHD and high energy physics projects (Peter Marston). Recent progress in selected technology and engineering areas is summarized below.

The Alcator C-MOD device, a new high-field tokamak to be built at MIT during 1987-1989, will test radio-frequency heating of the high-density plasmas that are characteristic of the conditions in a compact
The Alcator C-MOD design features cryogenically-cooled magnets, a demountable toroidal field magnet, a single-piece vacuum vessel, and a poloidal divertor. The toroidal field coils for Alcator C-MOD incorporate sliding joints which require innovative engineering design and tests to ensure reliability.

The Compact Ignition Tokamak (CIT) is proposed as a national project, to be completed in 1992, and to be located at the Princeton Plasma Physics Laboratory. It will be a copper, high-field ignition device patterned after the Alcator series at MIT. Bruce Montgomery is serving as Project Engineer, and Ronald Parker as Project Physicist. Richard Thome is manager for the poloidal field system, and Daniel Cohn is head of special studies. The CIT will require special laminated Inconel/copper plates for fabrication of the central solenoid and toroidal field coils. Practical bonding methods for these laminates are being developed for both CIT and Alcator C-MOD.

The International Tokamak Experimental Reactor (ITER) is a design and R&D activity which has grown out of a U.S./Soviet initiative at the Geneva Summit. The European Community and Japan have also been invited to participate in this three-year design and R&D effort. MIT is responsible for the U.S. poloidal field design and electromagnetics. It is hoped that this activity will result in the decision to proceed with the construction of an international fusion test reactor in the 1990-1991 time frame.

The divertor development group has been active in developing innovative designs for particle control, modular tokamaks and magnetic systems. A novel system to actively recycle plasma ions back into the plasma core from the boundary by a set of ripple coils below the plasma column has been fabricated for testing on the TEXT tokamak at the University of Texas. The method would induce an influx of circulating particles in order to reduce impurity generation and to enhance beam heating. The divertor development group is also developing innovative approaches to integrating tokamak magnets. These approaches would build the toroidal and poloidal field coils as single units to increase system maintainability.

The principal task involving the use of internally-cooled, cabled superconductors (ICCS) is the design of the two-meter outer-diameter Multipurpose Coil (MPC) which is a prototype of the central solenoid (ohmic heating) coils for fusion reactors. This task is multifaceted. It involves several collaborative efforts including: conductor sheath development in conjunction with Professor R. Ballinger; the development of a reliable commercial Nb3Sn superconductor with US wire vendors, including research to develop optimized low-AC-loss conductor in quantities suitable for reactor use; and a joint program with the Naka Fusion Research Institute of the Japanese Atomic Energy Research Institute that will allow testing of a prototype double-pancake coil of the type to be used for the outer coil of the MPC before the coil design is finalized. Conductor tests are being performed in conjunction with the Lawrence Livermore National Laboratory (LLNL), which is responsible for the design and construction of the inner coil of the MPC.

Basic research on high-field Nb3Sn and Nb-Al superconductors using powder metallurgical techniques has continued. Focus has been on small-scale hydrostatic extrusion processing and on extending practical processing technologies. Exploration of mechanical alloying and rapid quenching has been continued for Nb-Al. Current densities of \(10^4\) A/cm² at 20 T achieved in 1986, are expected to rise by an order-of-magnitude if the appropriate phase can be formed. Considerable activity has been underway during 1987 in collaboration with several research groups, evaluating the recently discovered high-temperature superconductors. DC fields up to 30 T, and pulsed fields up to 60 T are used for characterization.

The principal goal of MHD magnet design has been the development of a high-current conductor for large-scale MHD magnets based on the Internally-cooled, cabled superconductor (ICCS) design. To ensure that the conductors under development will meet the requirements of early commercial MHD magnets, an analytical and design effort has been performed on a preconceptual magnet based on input from the MHD community. Conceptual designs of space-based magnet systems for both linear and disk multi-megawatt MHD generators have also been developed.

Contributions to the high energy and nuclear physics program have included a continued role in assessing superconducting magnet designs for the Continuous Electron Beam Accelerator Facility's (CEBAF) spectrometers and toroidal large-acceptance detector, and continued involvement with the G-2 detector for an experiment at Brookhaven National Laboratory. The G-2 detector will measure, with precision heretofore impossible, the anomalous magnetic moment of the muon. Technical assistance has also been provided to the National Superconducting Cyclotron Laboratory at Michigan State University.

**FUSION SYSTEMS**

The Fusion Systems Division, headed by Daniel Cohn, investigates several aspects of fusion reactor conceptual design and develops advanced diagnostics. Research areas include: Compact Ignition Tokamak (CIT) and reactor system studies (Leslie Bromberg, Daniel Cohn and John Williams); safety and environmental studies (Mujid Kazimi); and advanced diagnostic development (Richard Petrasso and Paul Woskoboinikow). Selected technical advances are summarized below.
Compact Ignition Tokamak Design: There is active participation in a number of aspects of the design of the CIT, the next major tokamak device planned in the U.S. fusion program. This device will use high-field, high-performance copper-plate magnets. The national CIT design draws heavily on ignition experiment concepts and design features originated by the reactor studies group, particularly in the Long-Pulse Ignition Test Experiment (LITE) concept. Members of the Fusion Systems Division are currently working on the CIT project in the areas of magnet design, heating, burn control, and diagnostic development.

Reactor Systems Studies: Concepts have been developed for tokamak reactors using high-field superconducting magnets. A number of advantages may be possible using high magnetic fields, leading to the possibility of lower-cost, simpler devices for engineering test reactor and commercial reactor goals. Use of state-of-the-art Nb$_3$Sn superconductors has been investigated. In addition, new design concepts using new high-temperature oxide superconductors have been developed, with emphasis on the potential advantages of the combination of very high fields and high-temperature superconductor operation. Substantial advantages may result if practical magnets can be developed. A possible development path for these materials has been identified and magnet development, as well as system studies activities, have been proposed.

Safety and Environmental Studies: Studies have been made of the relative safety advantages of the deuterium-tritium fuel cycle and the deuterium-deuterium fuel cycle. New approaches have been developed for modeling possible fires in certain types of fusion reactor blankets. There has been participation in a major national assessment of the economic and safety aspects of fusion power reactors.

X-Ray Diagnostics: Special X-ray imaging techniques have been developed and successfully applied to spatial and temporal measurements of impurities in tokamaks. New information about transport properties has been determined. Concepts for gamma-ray imaging to determine fusion reaction birth rates in an ignited plasma have been developed.

Millimeter-Wave (Gyrotron) Diagnostics: Millimeter-wave scattering from plasma fluctuations using a state-of-the-art gyrotron (electron cyclotron resonance maser) has been carried out in the TARA tandem mirror. A large variety of phenomena was observed. A concept has been developed for application of gyrotron scattering to measure the alpha-particle velocity distribution, the ion temperature, and micro-instabilities in the CIT device.

COHERENT ELECTROMAGNETIC WAVE GENERATION

A new Division on Coherent Electromagnetic Wave Generation was established last year in the Plasma Fusion Center. This Division is headed by George Bekefi and Richard Temkin. Its primary objective is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1 μm to 1 cm range. Particular emphasis is placed on the development of free electron lasers, gyrotrons and novel radiation sources. A second area of research (Ronald Davidson) relates to theoretical studies of the basic equilibrium and stability properties of nonneutral plasmas and intense charged particle beams, with applications to high-current accelerators, coherent radiation generation, and nonneutral electron flow in high-voltage diodes. A third area of research relates to basic theoretical and experimental investigations of laser-pumped, far infrared molecular gas lasers, including studies of laser tuning and efficiency. A fourth area of research is the relativistic magnetron, including studies of phase locking of magnetron operation at high peak power.

In the area of gyrotron research, pulsed gyrotrons with output powers in the 400-650 kW range at frequencies between 140 and 250 GHz have been studied experimentally. These represent new records in output power and frequency for gyrotron devices. Such gyrotrons can be developed by industry into long-pulse or CW tubes for application to plasma heating.

In the area of free electron lasers (FELs), experimental studies have been carried out on the amplification, phase coherence, efficiency enhancement, beam quality and optical guiding in a free electron laser. These results contribute to the basic understanding of this important new type of coherent radiation source. An outstanding issue in free electron laser research is the problem of optical guiding. One of the remarkable properties of the free electron laser, apart from its wavelength tunability and high efficiency, is the large phase shift which the resonant interaction induces in the amplified electromagnetic wave. Under proper circumstances this phase shift can have a sign such that the electromagnetic wave is refracted towards the axis of the electron beam, in a manner somewhat akin to the guiding properties of an optical fiber. This theoretically predicted behavior has important implications. Optical guiding would mitigate the effects of diffraction, and thereby allow the length of FEL wigglers to exceed the Rayleigh range. Such long wigglers are needed if free electron lasers are to operate either in the vacuum ultraviolet (VUV) or at high efficiencies in the infrared wavelength regime. Using the MIT free electron laser facility, the phenomenon of optical guiding has been demonstrated successfully. This is the first such experimental demonstration.

In addition to the above work, a new type of permanent magnet helical wiggler has been developed for free electron laser and gyrotron applications. The system consists of an assembly of staggered samarium-
cobalt magnets. Innovative wiggler configurations are being investigated, including a circular wiggler in which a rotating electron beam is surrounded by an assembly of samarium-cobalt magnets. A novel free electron laser device using a gyrotron-powered electromagnetic wave wiggler has been designed. A long-pulse relativistic magnetron microwave source using a superconducting magnet has also been designed and is under construction. A far infrared molecular gas laser with narrow bandwidth emission has been demonstrated. Finally, a 140 GHz cyclotron autoresonance maser (CARM) amplifier with high efficiency has been designed, and numerical modeling has been carried out.

APPOINTMENTS AND PROMOTIONS

During the past year, there have been several important appointments and promotions in Plasma Fusion Center program areas.

Appointments include: Jiri Becvar (Data Precision), appointed Electrical Engineer in the Mirror Confinement Experiments Division; Carol Bonomo (Massachusetts Institute of Technology), appointed Assistant Fiscal Officer in the Fiscal Office; Dr. Shien-Chi Chen (AT&T Bell Laboratories), appointed Experimental Research Scientist in the Coherent Electromagnetic Wave Generation Division; Peter Hamilton (Cornell University), appointed Assistant Fiscal Officer in the Fiscal Office; Caia Grisar (MIT Lincoln Laboratory), appointed Applications Programmer in the Mirror Confinement Experiments Division; Dr. Chi-Tien Hsu (University of Texas at Austin), appointed Postdoctoral Research Scientist in the Applied Physics Research Division; Rui Vieira (Northeastern University), appointed Mechanical Engineer in the Toroidal Confinement Experiments Division; and Alice Wyman (Massachusetts Institute of Technology), appointed Alcator C-MOD Project Coordinator in the Toroidal Confinement Experiments Division.

During the past year, promotions in the Plasma Fusion Center have included: Joyce Cooper, promoted to Manager of Headquarters Operations Administration; Dr. Stephen Golovato, promoted to Leader, RF Heating Physics Group, in the Mirror Confinement Experiments Division; David Gwinn, promoted to Project Manager of Alcator C-MOD, in the Toroidal Confinement Experiments Division; Dr. Jay Kesner, promoted to Senior Research Scientist in the Plasma Fusion Center; Linda Knaack, promoted to Associate Fiscal Officer in the Fiscal Office; Michael Steeves, promoted to Project Manager, Japan MPC Superconducting Coil, in the Fusion Technology and Engineering Division; Dr. Richard Thome, promoted to Principal Research Engineer in the Plasma Fusion Center; Dr. Stephen Wolfe, promoted to Scientific Coordinator of Alcator C-MOD, in the Toroidal Confinement Experiments Division; and Dr. Jonathan Wurtele, promoted to Assistant Professor in the Physics Department.

The Plasma Fusion Center has also hosted several Visiting Scientists in the various research programs. They are: Dr. Franklin Chang-Diaz (NASA), plasma propulsion; Dr. Teruji Cho (University of Tsukuba, Japan), particle confinement studies on TARA; Prof. John Davies (Clark University), theory of free electron lasers; Dr. Vadim Dudnikov (Institute of Nuclear Physics, USSR), TARA experiments; Prof. Steve Fetter (Harvard University), economic, safety and environmental aspects of fusion; Dr. Henry P. Freund (Science Applications International Corporation), theory of free electron lasers; Dr. Vladimir Fuchs (Sciences de Bases, Quebec), plasma heating and current drive; Dr. Martin Gunderson (University of Southern California), plasma and electrode phenomena; Dr. Michael A. Hayes (Dartmouth College), Versator electron cyclotron heating program; Dr. Tadashi Ichihara (Mitsubishi Electric Corporation, Japan), superconducting magnet studies; Dr. Atsushi Ishiyama (Matsuta University), superconducting magnet studies; Dr. Elizabeth Källne (Joint European Torus), soft X-ray emission from Alcator C; Dr. Jan Källne (Joint European Torus), soft X-ray emission from Alcator C; Dr. Ryuhei Kumaizawa (Nagoya University), mirror experiments and diagnostic studies of RF-heated plasmas; Dr. Zhihong Lu (Southwestern Institute of Physics, Sichuan, PRC), RF heating experiments; Dr. Gulshi Luan (Institute of Plasma Physics, Academia Sinica, PRC), advanced tokamak systems and plasma-wall interactions; Dr. Igor Maksimov (Gorky State University, USSR, and IREX), superconducting magnet studies and cryomechanics; Dr. Michael E. Mauel (Columbia University), TARA heating experiments; Dr. Vladimir Pastukhov (Kurchatov Institute, USSR), TARA experiments; Dr. Lajos Pocs (Central Research Institute for Physics, Hungary, and IREX), particle reflux experiments in TARA; Dr. Hirohama Sato (Institute of Space and Astronautical Science, Japan), high-power gyrotrons; Dr. Frederick Seguin (American Science and Engineering), impurity transport and MHD phenomena in Alcator C and X-ray tomography on TARA and Constance; Dr. Amarjit Singh (Central Electronics Engineering Research Institute, India), high-frequency gyrotron studies; Dr. Naftali Tishby (Chaim Weizmann Fellowship), theory of stochasticity; Dr. Trach-Minh Tran (National Science Foundation, Switzerland), gyrotron and free electron laser theory; Dr. Akira Tsuchima (Tohoku University, Japan), end-wall potential control on Constance; Dr. Chun-Yi Wang (Zhejiang University, PRC), theoretical and experimental aspects of high frequency gyrotrons; Dr. Yin-Ming Tao (Institute of Physics, Chinese Academy of Sciences), gyrotron heating experiments on TARA; and Dr. Yasuyoshi Yasaka (Kyoto University), RF ponderomotive stabilization.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas:
Sandra Brereton, Ph.D. in Nuclear Engineering; Mark Foord, Ph.D. in Nuclear Engineering; Gregory Francis,
Ph.D. in Physics; Chad Joshi, Ph.D. in Mechanical Engineering; Frederic Hartemann, Ph.D. in Physics; Robert Kaplan, Ph.D. in Physics; Kosuko Kato, Ph.D. in Nuclear Engineering; Tsang Lee, Ph.D. in Materials Science and Engineering; Jerry Martin, S.M. in Nuclear Engineering; Todd Mower, S.M. in Mechanical Engineering; Arnold Pachtman, Ph.D. in Nuclear Engineering; Patrick Phelan, S.M. in Mechanical Engineering; and Peter Yoon, Ph.D. in Nuclear Engineering.

We take this opportunity to wish these graduates success in their future professional endeavors.

RONALD C. DAVIDSON
INTRODUCTION

The Research Laboratory of Electronics (RLE) is the Institute's oldest interdisciplinary research laboratory, founded in 1946 as the natural continuation of the wartime Radiation Laboratory. Initially, RLE was formed to bring together interests in physics and electrical engineering to work on problems in electromagnetic radiation, circuits, and specialized vacuum tubes. Over the years, however, RLE has branched out in several directions, and in fact, has been the root from which many other MIT laboratories have grown. Research within RLE is conducted by approximately 75 faculty members who are affiliated with the Departments of Electrical Engineering and Computer Science, Physics, Chemistry, Materials Science and Engineering, Aeronautics and Astronautics, Nuclear Engineering, and Linguistics. During the past year, approximately 250 graduate students and 100 undergraduates have worked on research projects within RLE. Major support for this research is derived from the Joint Services Electronics Program (JSEP) of the Army, Navy, and Air Force; other Defense Department agencies; the Department of Energy (DOE); the National Science Foundation (NSF); the National Institutes of Health (NIH); and the National Aeronautics and Space Administration (NASA). This support is combined with substantial contributions from industry and private foundations. While RLE has a heterogeneous character, its organization can be seen in two major thrusts: one focused on electronics and optics, and the other centered on language, speech, and hearing. In addition, there are seven smaller focus areas and some individual research activities which have a small amount of coupling to other projects within RLE.

ELECTRONICS AND OPTICS

Research in this area covers the entire range from production and characterization of electronic materials to processing techniques, device invention and characterization, high-performance integrated circuit design, and techniques for architectural exploration aimed at high-performance design. RLE brings together experts in physical chemistry, condensed matter physics, electronic materials, device physics, processing innovation, high-performance integrated circuit design techniques, and architectural strategies for special purpose applications including digital signal processing and image processing.

Professor Sylvia T. Ceyer has conducted experiments in order to understand the dynamics of molecule-surface interactions. She has discovered a new mechanism for molecular dissociation on a surface, which has extended the current understanding of many processes such as plasma etching. Professor Keith Nelson continued study on the interaction of ultra-short light pulses with matter that will lead to a new understanding of the dynamics of chemical and structural change. These experiments have demonstrated the general occurrence of impulsive stimulated scattering when ultra-short pulses pass through matter, and have revealed effects important to all ultra-fast optics and spectroscopy applications.

In the Submicron Structures Laboratory, under the direction of Professor Henry I. Smith, further advances were made in understanding electron transport in semiconductor devices with feature sizes less than 0.1 μ. For the first time, observations were made of electron velocities at room temperature and 77°K that exceeded saturation velocity in these devices. In addition, ion beam-enhanced grain growth was developed and used to study fundamental mechanisms of growth in thin semiconductor films of high-crystalline quality on amorphous substrates. A theory that explains the general class of ion-assisted processes in the low-temperature processing of thin films was developed by Professor Carl V. Thompson. In addition, a new experimental technique was developed for statistical characterization of electromigration-induced failure in thin-film metallic interconnect structures. A new apparatus was constructed that allows (for the first time) correlation of solidification conditions, interface morphologies, and crystalline defect structures at the liquid-solid interface during zone melting recrystallization of thin films. Under the direction of Principal Research Scientist John Melngailis, two focused ion beam machines were installed at MIT. Ion beam-induced deposition (with a resolution of 1/2 μ) was achieved, as well as novel device fabrication with sophisticated doping profiles.

In the optics research area, Professor Clifton Fonstad constructed a laser diode array that avoids previous limitations due to a double-lobed output beam. He also extended a modular microwave-equivalent circuit model for dielectric waveguide structures which is highly accurate, yet modest in computational requirements. Professor Hermann Haus designed an all-optical switch, based on interferometric techniques that permit an exact quantum mechanical solution. This switch theory promises to become an important special case study in the quantum theory of measurement. Observations of femtosecond scattering processes in gallium arsenide semiconductors, by Professors Erich P. Ippen and James
G. Fujimoto, have led to the fastest scattering times observed to date. Ultra-fast nonequilibrium electronic energy transport in metal films was also discovered. This raises the possibility of new devices based on nonequilibrium transport. In addition, Professor Fujimoto began a program in laser medicine, in collaboration with investigators at the Massachusetts General Hospital and the Massachusetts Eye & Ear Infirmary. Initial studies of laser-tissue interaction in the femtosecond regime were made. New techniques to investigate transient processes in laser-tissue interaction and laser medicine were also developed. Professor Peter Wolff's studies of optical nonlinearities focused on mercury telluride, which has a large third-order nonlinear optic susceptibility, the largest currently known with a picosecond response time. This nonlinearity is especially useful since it does not saturate below one milliwatt per square centimeter. At that intensity, its dielectric constant can be modulated by more than 10 percent in four-wave mixing experiments.

In condensed matter physics, both theoretical and experimental studies are coordinated to provide insight into a variety of novel states of matter. Professor A. Nihat Berker applied detailed renormalization-group calculations which, for the first time on random field systems, resulted in the discovery of a novel "hybrid-order" phase transition and a singularity in critical properties as a function of spatial dimension. This work is closely related to experimental studies by Professor Robert J. Birgeneau on tungsten metal surfaces. The system of hydrogen chemisorbed onto a tungsten (100) surface has been traditionally regarded as a prototypical system for the study of chemisorption on a reconstructing substrate. By using grazing incidence synchrotron x-ray diffraction, a lattice gas model was developed for this process, and resulted in a highly sophisticated picture of surface structure evolution as a function of hydrogen exposure. Professor John Joannopoulos performed the first ab initio theoretical investigation of gallium arsenide (111) and gallium arsenide (111) surfaces. Predictions include the microscopic reconstruction geometries for a variety of stoichiometries for (2x2) and (\sqrt{15}x\sqrt{15}) structures, the chemical potentials for phase transitions between various geometries, and the possible reaction pathways that can lead to the growth of specific geometries. This combination of theoretical and experimental work promotes a new understanding of chemisorption processes and epitaxial growth, which is essential to modern submicron technologies. Professors Marc Kastner and Patrick Lee studied electron transport in submicron silicon MOSFETs at ultra-low temperatures to understand how electrons behave when confined to very narrow dimensions. Special features associated with temperature-induced transitions from localized to extended states have been discovered and explained theoretically. This work in condensed matter physics is strongly related to fabrication technologies currently being developed in RLE's Submicron Structures Laboratory, under the direction of Professor Smith. This relationship exemplifies how interdisciplinary research can further both important theories and significant technologies. Professor J. David Litster studied the growth of colloidal crystals as models for epitaxial growth studies on patterned substrates. Surface-sensitive x-ray scattering techniques were applied to Langmuir-Blodgett films, which are very thin and have potential as insulators for high-performance device applications. They are also model systems for studying the structure of two-dimensional materials.
Klatt also completed a review of text-to-speech conversion for English, and a characterization of models for speech perception provided by many contemporary investigators. Principal Research Scientist Joseph Perrin completed a sophisticated movement transducer system for speech production which, for the first time, allowed access to detailed articulatory movements without the need for high dosage x-rays. This apparatus is significant because, while the study of articulation is fundamental to speech production, there had been major difficulties in acquiring substantial data on which to base theoretical understanding. A major effort focused on the acoustic-phonetic bases for speech recognition was led by Professor Victor Zue, who developed techniques for hierarchical segmentation and labelling that permit construction of a large speech database. In addition, new auditory models which match physiological and psychological measurements are being adapted for use in phonetically based speech recognition systems.

Perceptual research on sensory communication via hearing and touch was conducted by Professor Louis Braida, Senior Research Scientist Nathaniel Durlach, Principal Research Scientist Steven Colburn, and Research Scientists William Rabinowitz, Charlotte Reed, and Patrick Zurek. These basic studies will lead to new models of monaural and binaural sound detection and discrimination. In addition, they will contribute to a better understanding of hearing impairments and improved design of prosthetic devices that will provide signals either to impaired ears, or to the skin in the case of profound deafness. New knowledge of impaired speech perception in noisy environments has also been acquired, leading to the development of adaptive, multi-microphone hearing aids that afford large reductions in environmental noise, even in realistically reverberant environments.

In cooperation with the Eaton-Peabody Laboratory at the Massachusetts Eye & Ear Infirmary, long-range studies on the peripheral auditory system are being pursued. The primary emphasis is on transduction mechanisms for the acoustic signal to the hearing apparatus, the effect of efferent control in the middle ear and in the cochlea, understanding the transduction process at the cochlear hair cells, and the design and characterization of intra-cochlear auditory prostheses. Professor William Peake and Research Scientist John Rosowski have focused on how acoustic signals are coupled into the ears of different vertebrate species. Measurements in the alligator lizard have demonstrated that signal coupling through the skin plays a significant role in reducing the ear's sensitivity to airborne sound at low frequencies, a feature that may differentiate amphibians and reptiles from mammals and birds. Professor Nelson Kiang conducted studies on feedback in the peripheral auditory system, with particular attention to the diagnosis and treatment of hearing disorders. New comprehension of middle ear acoustic reflexes, and reflexes involving olivocochlear innervation of hair cells, has shown how this activity can affect the information processing of complex stimuli such as speech. Principal Research Scientist John Guinan demonstrated functional segregation of motor neurons in the middle ear, depending on whether they responded to sound in the ipsilateral ear or the contralateral ear. This has provided a new insight into neural pathways within the brain stem. Dr. Guinan has also obtained strong evidence that activity in olivocochlear efferents change the vibration pattern of the basilar membrane in response to sound. This knowledge has brought new perspective on the active nature of speech perception. Professor Thomas Nebis, Professor Lawrence Frishkopf, and Dr. Dennis Freeman studied the fluid mechanics of hair bundle motion in the cochlea. A major theoretical study revealed that fluid inertia, which was not included in previous studies, plays a critical role in the mechanics of hair bundles within the cochlea. From the complementary experimental perspective, a new device was designed and constructed to allow resolution of nanometer movements of such structures imaged by a light microscope on a photodiode pair. Thus, experimental confirmation of theoretical predictions about these minute structures is permitted. Experiments with intracochlear electrodes were conducted by Research Scientist Donald Eddington to furnish a rational basis for improving implanted prosthetic devices. A new electro-anatomical model of the human cochlea was developed which enhances the ability to investigate the effects of electrode geometry, interpret psychophysical experiments in subjects with implants, and investigate the complex interaction of electric fields during multi-electrode stimulation. The continued testing of speech perception in subjects with implants has demonstrated the benefit received from these devices.

FOCUS AREAS

Atomic, Molecular, and Optical Physics

Professor Shaoul Exekiel studied single-photon and two-photon interactions with atoms, clarifying the previously unexplained asymmetry in the observed spectrum of resonance fluorescence for an atom in a field gradient. These significant results in atom-field theory indicate that it is practically impossible to achieve a perfectly symmetric line shape. Work on a Raman atomic clock recently improved stability by a factor of three, which is very close to the quantum noise limit. In addition, continuing studies of optical gyroscopes demonstrated lock-in behavior in a passive resonator gyroscope, leading to a new, simple method of testing the quality of laser gyroscopes before final assembly. Professor David Pritchard made dramatic advances in the trapping of neutral atoms. As many as 10^9 atoms have been trapped for approximately 100 seconds, thus advancing the state of the art in both the number of atoms trapped and the confinement time by two to four orders of magnitude. This has permitted new experiments to be conducted on these isolated, ultra-cold atomic gases.
**Plasma Physics**

Professor George Bekefi provided the first experimental demonstration of optical guiding in free-electron lasers. In these lasers, the resonant interaction induces a large phase shift in the amplified magnetic wave. Under proper circumstances, this phase shift can have a sign so that the electromagnetic wave is refracted toward the axis of the electron beam in a manner similar to the guiding properties of an optical fiber. This new type of guiding is necessary to the operation of free-electron lasers in either the vacuum ultraviolet regime or at high efficiencies in the infrared wavelength regime. Professor Bruno Coppi made significant contributions to the theory of radial energy balance and thermal transport in thermonuclear plasmas. In the past, Professor Coppi’s theoretical results on anomalous ion thermal conductivity supplied a theoretical basis for the ALCATOR pellet injection experiments that achieved record values of the confinement parameter $\bar{N}$. Now, a novel principle of "profile consistency" has been employed to show that global characteristics of the plasma column severely restrict allowable temperature profiles to a canonical class, leading to a new understanding of self-regulating processes that control the evolution of the electron temperature in auxiliary-heated tokamak reactors.

**Radio Astronomy**

Professor Bernard Burke carried out a search for new gravitationally-lensed quasars, and produced approximately 4,000 radio maps captured by the Very Large Array (VLA) which revealed several promising candidate objects. Professor Burke collaborated with other U. S. and European investigators on the establishment of a Very-Large-Baseline Interferometer (VLBI) space station, which would provide a higher angular resolution than those achieved with earth-based VLBI stations alone. Professor John Dreher discovered a new "counter-jet" in the radio galaxy Cygnus A, and also started one of the largest observation projects undertaken at the VLA to extend these methods to a larger selection of radio galaxies. Professor David Staelin and Dr. Michael Shao completed a new stellar interferometer at the Mt. Wilson Observatory. This interferometer yields an improvement of a factor of five in astrometric measurements over traditional monochromatic observations. The images obtained from a passive 118 GHz spectrometer revealed that the abundance and altitude of ice produced in strong convective storms can be monitored from future satellites, and that such instruments can sensitively measure atmospheric temperature profiles, even in the presence of a variety of clouds.

**Image Processing**

Professor Donald Troxel developed a novel shading algorithm together with efficient hidden surface algorithms to produce high-quality pictures at minimal computational cost. Professor William Schreiber continued to lead a large advanced television research program aimed at the development of scientific and technological bases to improve picture and sound quality in television systems. A new frequency modulation system was developed to improve the efficiency of television transmission. A series of audience tests were carried out to assess viewer reaction to several aspects of image and sound quality. In collaboration with Professor David Staelin, new techniques were developed for motion-compensated noise reduction. Coding techniques were also completed that are appropriate to very low bit-rate representations of video signals.

**Digital Signal Processing**

Professor Alan Oppenheim completed the implementation of a new language for an intelligent signal processing workstation. The language successfully incorporates symbolic rearrangement of signal processing expressions. The combination of symbolic and numeric techniques in one advanced workstation provides substantially increased power and flexibility in signal processing applications. New algorithms were achieved to recover speech signals from highly degraded waveforms, and techniques were developed to reconstruct images from sampling strategies based on threshold crossings. Professor Bruce Musious developed a unique approach in the design of fault-tolerant multiprocessors for signal processing, where faults on multiple processors that perform linear computation can be detected and corrected by using a small amount of redundant computation. A new program was demonstrated that extracts integrated circuit design masks from ideal line drawings which represent a chip layout. This program incorporated knowledge about the VLSI fabrication process in order to assist in this image understanding task. A 16x16 cellular single-instruction/multiple-data-stream array of bit-serial processors was used to efficiently implement several experimental parallel image processing algorithms.

**Electromagnetics**

Professor Jin Au Kong completed studies of electromagnetic wave propagation in integrated circuit substrates through direct calculation of the transient response obtained by combining methods of characteristics and perturbational series under given circuit parameters. New theoretical models were
demonstrated, and are applicable to the active and passive remote sensing of a variety of practical scenes which are important for accurate terrain classification. Research Scientist Min Chang Lee developed a new understanding of the generation of artificial plasma layers in the lower atmosphere by high-power microwaves, and also characterized the effects on radio wave propagation of space shuttle-induced upper atmospheric disturbances.

Communications

Professor Jeffrey Shapiro established fundamental semi-classical and quantum analyses for closed-loop photodetection schemes used in the application of squeezed state and other nonclassical light beams. Professor Shapiro also developed theoretical models for the impact of target, atmospheric, and receiver noise fluctuations on the design and performance of coherent laser radars. He also experimented with the network utility of atmospheric optical communications, where cables are not possible. Dr. Robert Rediker studied the feasibility of producing high-powered lasers based on semiconductors. He obtained the near-field intensity and phase distributions needed to operate a coherent ensemble of these lasers. In addition, Dr. Rediker demonstrated the tunability of the output from this ensemble by changing the effective period of the spatial filter employed in this scheme.

Individual Research Projects

In addition to the focus areas described above, several other research directions are pursued within RLE. Professor Jerome Lettvin recently provided new experimental and theoretical understanding of dyslexic visual perception, and contributed a new insight into color perception. Realistic neuron models were used in new VLSI-based neural networks to provide accurate simulation of biological behavior. Professor John King applied techniques of molecule microscopy to detect water in biomaterials through the use of standing sound waves to extend the accuracy limit by a factor of $10^{-5}$. Professor Sow-Hsin Chen successfully studied the structure and dynamics of colloidal solutions using small-angle neutron scattering and photon correlation spectroscopy. In addition, he developed a new laser absorbing technique to remove thrombus in occluded arteries.

JONATHAN ALLEN
Congress established the Sea Grant College Program in 1966 to address the need for responsible development and management of marine resources. Existing programs of marine research and education at the nation's universities were recognized as important sources of information in this emerging field, and so a national program was created to provide them with financial support. MIT joined the Sea Grant network in 1969 when the Department of Ocean Engineering received a grant to develop a series of innovative texts. One year later, a larger "Sea Grant" was made to the Institute for a full research and education program. By 1976, MIT's Sea Grant contribution was so significant that the Institute was designated a Sea Grant College Program, the first private university to receive this recognition.

There are 29 university-based Sea Grant Programs throughout the coastal and Great Lakes States. Funds are distributed among programs in a competing grant process by the National Oceanic and Atmospheric Administration through the National Sea Grant Office. Each program is required to match its federal grant with at least one third from other sources including industry, state and local governments, universities, or private foundations. Congress established this matching provision to ensure that Sea Grant universities would be responsive to public and industry needs, to encourage cooperation between those who would do the research and those who would use it, and to foster more efficient technology transfer.

Last year the National Sea Grant Program provided the Institute with $1.7 million in support; this was matched by $1.3 million from industry, the Commonwealth, and MIT. Sea Grant also received $500,000 in related research support from several federal agencies. In all, these funds supported 22 faculty and 38 students from seven departments including Ocean, Civil, Mechanical, and Electrical Engineering; Applied Biological Sciences; Earth, Atmospheric, and Planetary Sciences; and Physics.

RESEARCH

The direction of Sea Grant research at MIT is guided by both the unique resources of the Institute and the needs of the marine community. At present, this research is focused on five areas: coastal processes; living resource utilization; offshore facilities; unmanned underwater work vehicles; and technology development and management for ocean uses, including the Sea Grant Marine Research Center. In some of these research areas, investigators from other Massachusetts universities are also participants.

Interdisciplinary Sea Grant investigations of coastal processes seek to describe and model the behavior of currents, sediments, and organic and inorganic compounds. Last year's projects included: modelling and measuring sewage effluent in Boston Harbor, designing a portable probe for measuring volatile pollutants in the field, examining the response of fine sediment to wave action, measuring natural and waste particles in coastal waters, and describing the microbial processes which influence the cycling of trace metals in urban estuaries. Results of this research will be incorporated into a nearshore simulation model which will help predict the fate and effects of pollutants, especially in Boston Harbor and Massachusetts Bay.

Research in the area of living resource utilization has expanded in recent years as a result of advances in biotechnology and genetic engineering. In addition to improving fishing gear efficiency, Sea Grant investigators in the last year have collected data on the Omega-3 fatty acid content of locally available fish. Their results suggest that several underutilized species may soon be commercially valuable because they are rich in these healthful oils. A genetic engineering study has developed DNA probes to monitor coliform bacteria, indicators of sewage contamination in marine environments; another research team has used marine biopolymers to encapsulate enzymes and drugs for controlled release in foods and pharmaceuticals. In continuing research, investigators are working to isolate a bioactive compound from shark cartilage which has proven effective in limiting the growth of new blood vessels around tumors; sharks were also used this past year as models for cataract studies and the development of anti-cataract drugs.

As offshore operations move into deeper waters, industry and government require state-of-the-art technology to build structures that are both economical and safe. Towards this end, Sea Grant research in offshore structures this past year has included: studies of open-ended pile-soil interactions, which have yielded information that may be used to develop more reliable methods for designing marine piles and predicting their behavior in marine clay sediments; the development of improved methods for sampling offshore sediments and better estimating in-situ soil conditions, a critical element for reliable geotechnical designs; and tests that have demonstrated, at least initially, that superconducting devices (SQUIDS) can be used to detect corrosion, and may prove to be a powerful tool for early detection and prediction of loss due to corrosion in offshore structures.
Sea Grant receives support from the Navy to study the operational behavior of marine ropes and cables. This research, prompted by safety concerns and hazard prevention, has yielded valuable data on the pathology of synthetic rope deterioration and the effects of abrasion and tensile loading on rope strength. Investigators are now developing models that will predict breaking points and working lives of ropes in a variety of marine applications.

Sea Grant research in the area of unmanned underwater vehicles has grown in the last few years as a result of increased industry support and rapidly advancing technologies in this field. The basic goal is to develop systems which supplement the capabilities of divers and manned submersibles, resulting in safer, more economical underwater operations. Last year researchers continued to study the effects of tether dynamics on vehicle performance, and began work on computer-aided control of a vehicle with a manipulator arm and camera. Another research team added quantitative photographic equipment, a multiple sampling device, and other data collection improvements to an unmanned vehicle for benthic biological studies. Finally, to develop technologies necessary to locate a vehicle in its environment, one project is using a laser/sonar ranging system to generate a three-dimensional computer model of the underwater work environment. Such a system could be used, for example, to survey the legs of a damaged platform and develop repair strategies for the actual operating environment.

Drawing upon many years of experience in basic unmanned underwater vehicle technologies, Sea Grant assembled a multidisciplinary research team from MIT and the Deep Submergence Lab at the Woods Hole Oceanographic Institution to assess the current technology of submersibles and propose a plan for developing the next generation of such vehicles. This important project, which defines future directions for underwater vehicle research, was supported by Navy funds.

In the area of new technology development, computer-aided engineering should have exciting applications in the design of marine systems. Sea Grant research this past year has focused on developing basic tools for geometric modeling which will address issues of design, analysis, simulation, fabrication and maintenance of ocean systems. Based on this research, a young professor in Ocean Engineering has developed a new technique to address the surface-to-surface intersection problem, an issue of fundamental importance to modern design and fabrication techniques. His work has already attracted support from the National Science Foundation and industry. In related work, Sea Grant organized a multidisciplinary team from Material Sciences, Ocean and Mechanical Engineering to develop models for shipyard fabrication techniques. This research, which is receiving support from the Office of Naval Research, may form the basis for improving the cost-effectiveness of this vital industry.

To enhance technology transfer, MIT Sea Grant created the Marine Research Center -- a relatively new, and to date successful, program of research undertaken with the financial support of partners in marine industry. Through the Center, companies provide research funds to facilitate the transfer of technologies from MIT laboratories to their own, and Sea Grant is advised of industry interests and needs in ocean research. Two of this year's Marine Center projects -- a study of the pile system for tension leg platforms, and another of the vibration of drill strips -- both focused on transferring technology to the offshore industry to enhance deep water operations. Based on the success of this industry interaction, the Marine Center model was expanded to include other industries and interests. A newly-formed partnership with the industrial company involved in the clean-up of Boston Harbor and Massachusetts Bay will allow Sea Grant to transfer technological expertise to those who will do the work, and to identify voids in our knowledge that may be used to guide future Sea Grant research. In the area of computer-aided engineering, the Marine Center is working with industry to develop more robust intersection algorithms and create new techniques for shape representation, both important areas in the new and emerging field of computational geometry.

ADVISORY SERVICES

There are three parts to MIT's advisory service -- the Marine Industry Collegium, the Marine Advisory and Fisheries Engineering Service, and the Communications/Information Service. The Collegium, modeled on the Industrial Liaison Program, is a fee-for-membership organization which fosters industry-institute cooperation. Collegium membership entitles companies to attend several technical workshops each year to meet with faculty and students to discuss and review research in progress. Last year workshops were held on teleoperation and autonomous underwater vehicles; industrial applications of chitin and its derivatives; dynamics of marine cable systems; and the pathology, abrasion, and fatigue of synthetic ropes.

The Sea Grant Marine Advisory and Fisheries Engineering Service serves a local, regional and national constituency. Within this service, the Center for Fisheries Engineering Research, now in its fifth year, has evolved into an important technical resource. The Center uses the Naval Ship Research Development Center in Bethesda, Maryland to test scale model trawl systems. To improve model testing capabilities, the Center sponsored a research team from the Department of Mechanical Engineering to develop a system for determining the X-Y-Z coordinates of points on a model net using a
computer-controlled pair of laser beams. Another project, jointly sponsored by industry, is perfecting a towed system for in-situ trawl and fish observation. To improve the safety and design of fishing vessels, the damping abilities of various anti-rolling devices and model fish-boat paravanes are being tested.

For the fourth year, the Sea Grant Advisory Service coordinated COASTWEEKS, a statewide event that involved over 60 organizations and attracted 24,000 participants in programs designed to increase the public's appreciation and management of coastal resources. Advisory Services also worked with the New England Aquarium to develop a circulation model, based on MIT research, that will be an integral part of their new exhibit on Boston Harbor.

In the Communications/Information area, 22 reports were added to the Sea Grant publication series which was initiated in 1970. A complete series of these reports is housed in the Marine Information Center, a small reference facility; also on file are a complete set of WHOI reports and publications from the entire Sea Grant network. Members of the MIT community, marine businesses, and the general public use the Information Center regularly; a PC-based catalog system allows quick, efficient response to information requests. Communications/Information produces MIT Sea Grant's newsletter, the MIT Sea Grant Quarterly Report, and the information directory, Marine-Related Research at MIT. As a result of press releases and media contact, articles citing MIT Sea Grant research and advisory activities appeared in several national publications including the New York Times, Smithsonian magazine, New England Business, and Science News.

EDUCATION

The educational goals of Sea Grant are to provide learning opportunities to university students, professionals, and the public. Support for graduate students is included in almost every research project. In addition, the program continues to increase the number of grants awarded through the Undergraduate Research Opportunities Program. In 1986-87, eight UROP awards were given in the fall semester and ten in the spring to undergraduates in the departments of Ocean Engineering, Earth, Atmospheric and Planetary Sciences, Mechanical Engineering, and Civil Engineering.

The Dean A. Horn Undergraduate Award, established in 1982 to honor the contributions of a former Sea Grant director, was given to Alessandro Bocconcelli, of Ocean Engineering, for his field research on the towing power of trawlers. Sea Grant also awarded two students partial scholarships to accompany a research cruise to the Pacific.

Efforts to increase educational opportunities in ocean research were rewarded last year by a scholarship grant from the H.A. Perry Foundation, Inc., which will support a graduate student in the area of unmanned underwater vehicles. Sea Grant also encouraged an alumnus to donate a suite of computer-aided design software for developing wind-enhanced systems for ships. Added to the Athena network, this software will be available for a variety of studies in Ocean Engineering.

Last year, the 15th Annual Sea Grant Lecture and the 5th Annual Sea Grant Seminar series were held in October on Undersea Teleoperators and Intelligent Autonomous Vehicles. The program discussed the history of teleoperation and the evolution of remotely operated underwater systems, and presented the state-of-the-art information on this rapidly developing technology. Plans are now under way for the next Lecture Seminar series to be held in October on Health Effects of Omega-3 Fatty Acids: Fish Oil and Other Sources.

MIT continued its jointly sponsored program of continuing education for New England fishermen with the Massachusetts Maritime Academy and the Commonwealth of Massachusetts.

PROGRAM MANAGEMENT

The Program Director is Professor Chryssostomos Chryssostomidis, of the Department of Ocean Engineering; Associate Research Directors are Marcus Karel, Professor in the Department of Applied Biological Sciences, and Keith D. Stolzenbach, Associate Professor in the Department of Civil Engineering. Norman Doelling continues as Executive Officer and oversees operations of Sea Grant advisory services. New to the staff are Elizabeth E. Tayntor, Manager of the Communications and Information Service, and Robert A. Davine, the Program's Administrative Officer.

To encourage the development of new research ideas, Sea Grant sponsors several seed projects each year, some of which go on to become full scale programs of research. Last year, a number of diverse projects including menhaden oil, braided composite laminates, and marine industry competitiveness received support.
Sea Grant administers the Doherty Professorship endowed by the Henry L. and Grace Doherty Foundation for young faculty at the Institute. In the spring of 1987, three new professors were named recipients of the chair -- Dale G. Karr, Assistant Professor in Ocean Engineering; Jean-Jacques Slotine, Assistant Professor in Mechanical Engineering; and S. Shyam Sunder, Associate Professor in Civil Engineering. Renee Fitts, Assistant Professor in Applied Biological Sciences, continues to hold the two-year appointment for a second year.

CHRYSOSTOMOS CHRYSSOSTOMIDIS
The Technology and Development Program's (TDP) primary objective is to provide a focus at MIT for research and education related to the role of science and technology in the socioeconomic growth of developing countries. The multidisciplinary program is a mechanism to bring faculty and students at MIT together with faculty and staff in foreign universities, research institutions, and government organizations. Its more specific objectives are to:

- Promote an awareness of the relationship between science, technology, and development on the part of faculty and students at MIT;
- Provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development;
- Assist the faculty, students, and staff of collaborating institutions in other countries to develop research and academic interests consistent with their national needs;
- Serve as a contact for interested organizations outside MIT (government, academic, private sector) to access the Institute's resources and its knowledge of developing countries—particularly of their socioeconomic and technological problems;

The TDP carries out its objectives through research, academic programs, and contacts with international and national organizations that are concerned with, or have an interest in, broad areas of technology and development. These activities are initiated on the basis of strong MIT faculty support and willingness to participate. The Program does not undertake research projects which require large-scale non-faculty staffing, and all research activities are supervised by faculty members.

The TDP's experience has been that through cooperation among institutions in developed and developing countries, science and technology can be put to more productive use. As a result of such cooperation, both developing and developed countries can reach a better understanding of their own scientific and technological needs.

The Program Director is Professor Fred Moavenzadeh, William E. Leonhard Professor of Engineering in the Department of Civil Engineering. Professor Nazli Choucri of the Department of Political Science is the Program's Associate Director and Chairman of the Policy Committee. Committee Members are Professors Moavenzadeh, Daniel M. Holland of the Sloan School of Management, and Jack P. Ruina of the Department of Electrical Engineering.

The following sections of this report summarize the specific activities undertaken by TDP in 1986/87.

NEW RESEARCH AND ACADEMIC INITIATIVES

The Middle East Program at MIT completed its first academic year, under the direction of Professor Nazli Choucri, TDP Associate Director. The purpose of the program is to enable students with an interest in the Middle East to develop an expertise in the area in addition to their own academic field of specialization. The program examines the processes of socioeconomic change, technological development, political change, institutional development, capital flows, and business and investment patterns in the region. Two interdepartmental graduate courses were offered by the Program during 1986/87: Politics, Technology, and Development in the Middle East; and Technology, Business, and Public Policy in the Middle East. Faculty members from the Department of Political Science, the History Faculty, the Department of Urban Studies and Planning, the Sloan School of Management, the Department of Civil Engineering, the Science, Technology, and Society program, and the Aga Khan Program in Islamic Architecture participated in the program.

The TDP continued its negotiations with the Kuwait Institute for Scientific Research and Kuwait University to establish a major collaborative program to expedite development of the scientific and engineering capabilities of these two institutions. The proposed scope of activities includes joint research projects and supplementary educational activities such as workshops, faculty exchange, short courses, and fellowships. Research areas of potential interest include energy, petrochemicals, public works, electronics, and oceanography. Professors Choucri, Moavenzadeh, and Holland visited Kuwait in January 1987 to discuss the program, and a new proposal was submitted by TDP to the two Kuwaiti organizations for further consideration.
The TDP entered into discussions with the Mitsubishi Research Institute in Tokyo concerning the establishment of a Global Infrastructure Fund (GIF), to support large-scale, multinational infrastructure projects. The proposed role of MIT, in a prefeasibility phase to be funded by Mitsubishi, would be to develop a GIF implementation plan and appropriate methodologies for project selection and analysis. Other academic institutions, such as the Harvard Law School, Technical University of Berlin, and Tokyo University, are also being considered as participants in this effort. A presentation was made to Mitsubishi executives in Tokyo concerning the proposed scope and funding of the prefeasibility phase, and the TDP is expecting a response during the summer of 1987.

Professor Fred Moavenzadeh and Professor Kenneth A. Smith, Associate Provost and Vice President for Research, met with representatives from the Universidade Estadual de Campinas (UNICAMP) in Brazil to discuss potential collaboration with MIT in the areas of chemistry, biotechnology, advanced informatics, and plasma physics.

CAIRO UNIVERSITY/MIT TECHNOLOGICAL PLANNING PROGRAM

Since 1977, the TDP has participated in a major program in Egypt to assist Cairo University in the establishment of a Development Research and Technological Planning Center (DRTPC). Modeled on similar centers at MIT, this organization now provides an institutional mechanism at Cairo University for conducting contract research on development topics with Egyptian and international organizations.

During the past academic year, the DRTPC showed a significant increase in its volume of sponsored research, from a total of LE 300,000 in 1985/86 to LE 750,000 in 1986/87. Fourteen individual projects were funded by ten Egyptian government and private sector organizations. Areas of research included transportation systems planning, urban infrastructure design, water resource management, materials testing methodologies, energy utilization modeling, and construction planning and management. Nine of these projects were the direct result of prior research undertaken by Cairo University faculty members in collaboration with counterparts at MIT.

The specific activities funded by the CU/MIT Program over the past year included the following:

CU/MIT Research

Since 1977 over $8.0 million has been allocated by TDP to academic departments at MIT for CU/MIT research. During 1986/87, the following projects were funded:

Solar Pond Technology

Solar ponds have been proven to be a cost effective energy alternative in environmental conditions similar to those prevailing in Egypt. The feasibility of solar pond technology is being demonstrated in this project through the construction of two demonstration ponds near Alexandria; one with a natural bottom, and another with an artificial lining. Physical, chemical, and geological data are being carefully monitored to evaluate pond performance, and to recommend future simulation and design techniques for larger ponds which will have electrical power generation capabilities. MIT Principal Investigator: Professor Donald R.F. Harleman, Department of Civil Engineering.

The Hydrology of Agriculture in Egypt

Two extreme conditions of irrigation exist in Egypt: (1) in the deserts, a situation of scarcity which calls for sprinkler and drip systems, and (2) in the Delta and other agricultural areas, an excess of irrigation activity which causes substantial loss of soil nutrients. Many areas also suffer from problems of alkalinity and salinity. This project therefore seeks to simulate water flow under different irrigation systems and under different types of soil stratification. Models are to be verified and applied to determine optimal irrigation scheduling for plant growth, preservation of nutrients, and control of salt accumulation. MIT Principal Investigators: Professors Rafael Bras and Peter Eagleson, Department of Civil Engineering.

Performance of the Egyptian Prefabricated Housing Industry

Improving the performance of the prefabricated housing companies has been designated by the Government of Egypt as an area of immediate concern. A joint CU/MIT team has been assembled to conduct a review and analysis of the individual companies, in order to recommend solutions to some of the most serious problems facing the industry. The project has focused on the following specific issues: simplification of precast elements to suit Egyptian conditions, implementation of company-wide planned maintenance programs, producing new floor plan designs to better fit standard prefabrication methods, and streamlining of management for better coordination between production, transportation, and assembly. MIT Principal Investigator: Professor Eric Diuhosch, Department of Architecture.
Engineering Design Capabilities in Egyptian Industry

A new CU/MIT project is being developed to upgrade the process, equipment, and plant engineering design capabilities of the Egyptian Sugar Company. It is expected that the findings and recommendations of this project will be used to develop similar projects in other industrial sectors in Egypt. Discussions are underway with Professor Elias Gyftopoulos of the Department of Nuclear Engineering to determine the scope of MIT's participation.

CU/MIT Educational Activities

Thirteen Cairo University faculty members and five graduate students were awarded fellowships under the ongoing CU/MIT program of doctoral and postdoctoral fellowships.

In October 1986 a seminar was held at the DRTPC on Management and Productivity. Over 100 representatives from public and private sector companies, academic institutions, and government agencies met to discuss the main factors influencing productivity in Egyptian industry, and measures that should be taken to improve overall productivity levels. Case studies were presented on three companies in the areas of meat and milk production, metals processing, and construction. Professor Elias Gyftopoulos represented MIT at this seminar.

A short course was held by the DRTPC on Construction Management during January 1987. Professors Robert Logcher and Fred Moavenzadeh, and Dr. James Paddock of the Department of Civil Engineering participated in several of the course sessions. Over 30 participants from Egyptian construction companies, financial institutions, consulting companies, and academic institutions attended to discuss the following topics: planning and resources in construction, monitoring and control, information systems, and financial management. Case studies were presented on the Shobra Electric Power Plant and the Cairo Underground Transportation System.

Also during January 1987, Professor Eric Dluhosch of the Department of Architecture presented a seminar to managers from the Egyptian prefabricated housing industry on planned maintenance systems. Professor Donald Harleman and Dr. E. Eric Adams of the Department of Civil Engineering presented a seminar on current trends in solar pond research to a group of Cairo University faculty members and officials from the Egyptian Ministry of Energy.

OTHER TDP ACTIVITIES AT MIT

Professor Nazli Choucri and Professor Myron Weiner of the Center for International Studies completed a research project for the Ford Foundation on "The Internationalization of Policies Affecting International Migration". The project focused on conditions under which unilateral, bilateral, regional, or other multilateral actions on international migration are pursued, and the consequences of these actions for both international migration and relations among states. Professor Choucri supervised a specific case study on migration in the Middle East.

In November 1986, the TDP held a Symposium on the Middle East at MIT focusing on the dual themes of security and stability in this area. Four central issues were discussed: Arab unity, the Arab-Israeli conflict, Islamic fundamentalism, and technological dependence. Faculty members from Harvard, Princeton, Columbia, Tufts, and several other U.S. universities attended the symposium.

The seminar series on "The Political Economy of the Middle East" was continued by TDP and the Center for International Affairs at Harvard. The TDP and MIT's Department of Political Science also continued their joint seminar series on "Development and Change in the Middle East".

Professor Nazli Choucri chaired a workshop on "Technology, Development, and Public Policy in the Middle East", at the 20th annual meeting of the Middle East Studies Association in November 1986. Professors Fred Moavenzadeh and Daniel Holland also participated in the panel discussion which focused on the role that science and technology have played in the socioeconomic development of the Middle East.

The TDP continued publication of its newsletter, "Technology and Development", and its series of technical reports. The proceedings of the "Roundtable on Science, Technology, and Development in Latin America" were also published during the past year. A complete list of available publications can be obtained from the TDP office, room E40-247.

FRED MOAVENZADEH
Technology Licensing Office

Fiscal Year 1987 has been the first year that the Technology Licensing Office (TLO) has operated under a new set of guidelines and motivations. Nearly two years ago we embarked on a major re-examination of what was then known as the Patent, Copyright, and Licensing Office. The faculty committee which accepted major responsibility for this review was chaired by Professor H. Kent Bowen of the Department of Materials Science and Engineering. The committee was ably assisted by Mr. Niels Reimers. Mr. Reimers is the director of technology licensing at Stanford University and he agreed to spend a one year sabbatical at MIT for the express purpose of helping us re-think these issues.

The Committee concluded that the first obligation of this Office is to provide an efficient mechanism for the transfer of technology to the public, and that licensing to industry is often the best means by which to achieve this dissemination. Protection of intellectual property by the acquisition of patents and copyrights is a lesser objective. The name of the former Patent, Copyright, and Licensing Office was therefore changed to the Technology Licensing Office in order to reflect this new focus.

The royalty sharing plan has also been changed to give inventors (or software authors) and their departments a more substantial share of royalty income received from significant inventions or software. As a result of its new focus, the TLO has executed over 45 patent licenses and over 45 software licenses this year, whereas the corresponding numbers for the period from July 1, 1985 to June 30, 1986, were 17 and 32 respectively.

Paced by a strong performance in software and biotech licenses, royalty revenue surpassed $3 million, up from $2.3 million last year. In addition, five smaller or startup companies paid some of their royalties in the form of equity. Any such shares are valued at zero relative to the royalty income reported above. Among the most exciting license agreements are:

1) Technology that could lead to the creation of new drugs that affect the human immune response to foreign substances. Applications would include the creation of a vaccine for AIDS or allergy drugs for ragweed pollen.

2) Technology that could lead to ductile high temperature superconductor wires.

We are pleased with the above results and expect this growth to continue during the next years. To help us accomplish this goal, two new Licensing Officers were added to our staff: Ron Scharlack, a mechanical engineer and MBA, and Amy Porter, a biotechnologist. Both bring extensive industrial and technological experience to our team.

JOHN T. PRESTON
Over the last three years, the Whitaker College has pursued the identification of fields in which MIT's special strength in science and engineering can be applied to promote research programs in the biological and medical sciences. To this end, the College has focused on five areas which serve as the basis for its divisions: three interdisciplinary programs, the Department of Brain and Cognitive Sciences, and the Clinical Research Center. This year I am pleased to report on the following events and highlights of our programs in bioengineering, human biology and experimental medicine, and health policy management. The activities of the Department of Brain and Cognitive Sciences and the Clinical Research Center are reported separately.

PROGRAMS IN BIOENGINEERING

To strengthen and develop our programs in bioengineering, we have concentrated our efforts and resources in two areas: (1) biological and medical imaging and (2) medicinal chemistry and drug delivery systems.

Biological and Medical Imaging

Biological and Medical Imaging (BMI) is a research and educational program that is undergoing a major transformation as a result of the resignation of Dr. Alan C. Nelson, formerly the Director of the Laboratory for Computer Assisted Microscopy. Now, under the leadership of Dr. Derek Rowell of the Department of Mechanical Engineering, efforts are under way to establish a state-of-the-art facility for the processing and analysis of medical and biological images. The objective is to be able to analyze images from a wide variety of fundamental and clinical data acquisition modalities, including nuclear magnetic resonance; computed tomographic scans; and transmission, scanning electronic, and optical microscopy.

Dr. Rowell has extensive experience in computer-based image manipulation, analysis, and display. In addition, a junior faculty search has led to the appointment of Dr. Van Wedeen, a physician with a background in mathematics and an established record in cardiovascular flow imaging using magnetic resonance imaging techniques. His primary appointment will be in the Whitaker College joint with the Media Laboratory.

Dr. Gordon L. Brownell, who has a primary appointment in the Department of Nuclear Engineering joint with the Whitaker College, has been extensively involved in studies on positron tomography (PT) imaging, which are carried out at the Physics Research Laboratory of Massachusetts General Hospital. The development of new positron imaging devices there has progressed, and studies are being carried out that investigate neural pathways and radiopharmaceutical distribution in mammalian brain on PCR-1, a high-resolution positron tomograph. The design of PCR-11, a cylindrical tomograph with even higher resolution, is continuing.

Academically, the biological and medical imaging program is tied to a doctoral program in Radiological Sciences. Funded in part by an NIH training grant that provides tuition and stipend support for six students, doctoral candidates are admitted to the Department of Nuclear Engineering. Students in the program pursue their academic and research objective in one of four specialty areas: medical, diagnostic, and therapeutic technology; radiation biophysics; radiopharmaceutical chemistry; or biological and medical image processing. While most core subjects are taken at MIT, student research is conducted at Harvard-affiliated hospitals and the Harvard School of Public Health, as well as the MIT Magnetic Resonance Imaging Facility of the National Magnet Laboratory and the College's Biological and Medical Image Processing Facility.

An important administrative activity of the Radiological Science program this year has been the search for new faculty for the academic year 1987-88.

Another important change related to imaging has been the decision to merge a portion of the resources and equipment of the College's Electron Microscopy Laboratory with the E.M. Facility of the Department of Biology (including the Center for Cancer Research) to form a joint facility located in Biology. This facility will be managed by a faculty committee formed with members of both departments. Scanning electron and optical microscopy services will remain available in the Whitaker facility at least until the end of the calendar year.

Finally, Dr. Robert Mann, Whitaker Professor of Biomedical Engineering in the Department of Mechanical Engineering, was appointed Director of Bioengineering Programs in the Whitaker College, effective July 1, 1986.
Program in Medicinal Chemistry and Controlled Drug Delivery System

Research in Dr. Robert Langer's laboratory has led to the development and synthesis of two new classes of biodegradable polymers. One class of polymers has been designed that releases only from the surface of the implant. A system that releases a drug only by surface erosion has several important advantages, including: (a) the ability to release a drug independent of the properties of the drug itself; (b) the ability to vary release rates linearly by varying the drug concentration in the device linearly; and (c) the maintenance of mechanical integrity.

An application has been made to the US Food and Drug Administration to begin clinical trials using these polymers to release drugs to treat human brain tumors. If approved, this will be the first synthetic polymer designed for drug delivery to reach this stage of development and testing.

A second class of biopolymers has been developed that is derived from amino acids. However, unlike all other polymers of this type, they are unique in that they are linked by non-amide bonds. For example, the laboratory is currently synthesizing polyesters of hydroxyproline, the major substituent of collagen, and polyiminocarbonates, using tryosine monomers. These latter polymers have properties that stimulate the immune system and have been used to produce very high titres of an entrapped vaccine in animals from a single injection. Potential applications for this approach include novel vaccines for AIDS or hepatitis.

Dr. Langer holds a joint appointment in the Whitaker College. His primary appointment is in the Department of Applied Biological Sciences.

Programs in Human Biology

Dr. Monty Krieger, Associate Professor in the Whitaker College and the Department of Biology, continues his program of studying the molecular mechanisms which underlie the functions of membrane glycoproteins, in general, and the low density lipoprotein (LDL) receptor, in particular. This year his work has been focused on three areas: (1) the detailed analysis of the biochemical and genetic defects in previously isolated Chinese hamster cell mutants with defects in the endocytosis of LDL and the isolation of new mutants; (2) the analysis of the functions of glycosylation, especially O-glycosylation, of membrane and secreted glycoproteins, including viral envelope glycoproteins such as those from the AIDS virus and the Epstein Barr virus; and (3) the development of a cell biological and genetic system for the study of intercellular junctional communication.

Dr. Krieger and his laboratory have made considerable progress in cloning the two genes (ldlB and ldlC genes) required for normal Golgi apparatus function and for the stability and function of LDL receptors. Using DNA transfection methods and techniques for revertant selection previously developed in his laboratory, he is exploiting species-specific repetitive DNA sequences to clone these genes. In the course of this work, cells have been isolated which appear to have an extragenic suppressor of ldlC. These cells may provide substantial insight into the mechanisms governing cholesterol homeostasis.

In collaboration with researchers at the Harvard Medical School, Dr. Krieger has also discovered that one of the LDL-receptor-deficient mutants, ldlD, exhibits a reversible defect in glycoprotein O-glycosylation. This mutant provides the first opportunity to examine the function of O-linked oligosaccharides on the intracellular processing of membrane and secreted proteins. A series of genes encoding a variety of glycoproteins is being transfected into the ldlD cells and the structure and intracellular processing of these glycoproteins is being studied. This work is important in learning more about basic cell biology and may help in formulating new strategies for vaccine and drug development.

Finally, Dr. Krieger's research has shown that expression of LDL receptor activity in one of the mutants can be made dependent on the formation of functional intercellular communicating junctions. As a consequence, it will be possible to use the vast array of tools already developed for the study of LDL receptor pathway to study junctional communication. This work is in its infancy, but it is an exciting prospect.

Dr. Krieger is the first recipient of the Latham Family Career Development Professorship for his outstanding contributions to both education and scholarship in biochemistry. His appointment will become tenured effective July 1, 1987.

Dr. Robert Rosenberg holds a joint appointment in the Whitaker College and Department of Biology. He is a professor of medicine at the Beth Israel Hospital and the Harvard Medical School. His laboratory has been investigating a variety of mechanisms involved in the regulation of normal blood vessel wall function and in the development of vascular disease in humans.

During the past year he has demonstrated that complex carbohydrate chains of heparin-like mucopolysaccharides with anticoagulant function are covalently linked to a unique set of hydrophobic core proteins which are integral components of the endothelial cell membrane. He has also reported the first cDNA and gene structures of bovine and human thrombomodulin. This protein is a specific receptor uniquely synthesized.
by endothelial cells that line the blood vessels and, like heparin, functions as a naturally occurring anticoagulant. The laboratory is currently investigating the regulatory processes underlying these phenomena.

Investigation of the cytoplasmic maturation of megakaryocytes, a specialized cell that is fragmented in order to produce platelets, has continued with the identification and isolation of several components which regulate cell maturation and number. Dr. Rosenberg is studying the regulatory processes responsible for megakaryocytopenesis and platelet production. Platelets are critical elements of the blood involved during thrombotic and arteriosclerotic events. Dr. Rosenberg's pioneering investigations should permit rapid development of these heretofore obscure areas.

PROGRAMS IN HEALTH POLICY MANAGEMENT

The Program in Health Policy and Management is the only PhD program of this kind in the country designed specifically for physicians and medical students. Fourteen highly qualified medical students and physicians have now been admitted to four entering classes.

Under the direction of Dr. Stan Finkelstein, this program is strongly interdisciplinary, drawing upon faculty from the Sloan School of Management and the Departments of Economics and Political Science, with the goal of providing training for physicians in the complexities of health care delivery. The graduates of this program will have competence in the management and economics of health care delivery, as well as an awareness of the political consequences of making decisions in the area of health. All classes have performed at a very high level and have been very positive about their educational experience. Support for the program and students is provided from funds granted to MIT by the Henry J. Kaiser Foundation.

Despite dedicated and effective management and the enrollment of competent professionals in the PhD program, the interdisciplinary linkages with other entities at MIT have not strengthened the program as originally planned over a decade ago. As a result, the decision was made this spring to discontinue the Health Policy Program. Arrangements have been made with Dr. Finkelstein and funds are available for the orderly completion of the degree programs of students currently enrolled.

Other Activities

Three seminars examining new and exciting areas in the field of neuroscience were held during the academic year as part of our Distinguished Lecture Series in the Brain Sciences, which we began in 1984. As in the past, the lectures and receptions that followed were very well attended by the Institute community.

Eleven predoctoral fellowships were awarded this spring to students working with faculty in the Whitaker College. The funds for these awards, which provide both tuition and stipend over a twelve-month period, are generously provided by the Surdna Foundation, Edward J. Poitras Fellowship funds, and the Whitaker Health Sciences Fund.

Faculty and Staff

In recognition for his past achievements, Dr. Rosenberg was the recipient of an Honorary Doctorate Degree from the University of Paris, France, in January, 1987.

Vera J. Ballard, formerly Administrative Officer of the Whitaker College, was named Assistant Director for Finance and Administration, effective January 1, 1987.

EMILIO BIZZI, M.D.
Director
This has been an exciting year for the Department of Brain and Cognitive Sciences. On July 1, 1986, in response to the Institute's growing commitment to research in the brain and cognitive sciences, faculty members in the Whitaker College working in computational neuroscience, systems neuroscience, and molecular neurobiology merged with the faculty of the Department of Psychology to form the Department of Brain and Cognitive Sciences. The purpose of this major reorganization was to integrate MIT's widespread efforts in the brain and cognitive sciences in one academic department under the auspices of Whitaker College. The College, with a focus on interdisciplinary research and education, is ideally suited to encourage and support collaborations across traditional academic disciplines.

The goal of the new department is to promote an interdisciplinary approach to the study of the brain that combines the experimental technologies of neurobiology and neuroscience with the theoretical advances coming from the field of artificial intelligence. The department is particularly renowned for its strength in computational neuroscience (visual and motor systems) and cognitive science. We have further broadened our scope through collaboration and joint appointments with the Artificial Intelligence Laboratory, the Department of Biology, the Department of Linguistics and Philosophy, the Department of Mechanical Engineering, and the Media Laboratory.

The Department has a faculty of twenty-nine, which includes five primary and two joint appointments made this year alone. In addition, three more faculty members will begin their appointments in FY'88. I would like to thank the various intra- and interdepartmental search committees and the Whitaker College Council for their tireless participation and effort in the search and selection process of a total of ten outstanding individuals over the past year.

RESEARCH

Research in the Department of Brain and Cognitive Sciences is structured around four main themes: neurobiology, systems neuroscience, computation, and cognition.

Neurobiology

Neurobiology deals with the biology of neurons with an emphasis on the special properties of neurons as encoders, transmitters, and processors of information. A detailed understanding of neuronal structure and functions requires application of the techniques and knowledge of contemporary molecular, cellular, and developmental biology. These biological disciplines are well represented in the Department through the establishment of joint appointments and interdisciplinary collaborations with the Department of Biology that provide the intellectual framework for exciting educational and research programs.

Primary areas of interest include (1) the development of neuronal morphology and connectivity, (2) the cellular and molecular basis of behavior in simple neuronal circuits, and (3) neurochemistry and cellular physiology.

Systems Neuroscience

Systems neuroscientists are concerned with vision and motor systems. The scientific aims are to understand transduction and encoding of sensory stimuli into nerve messages, the organization of sensory-motor systems, the processing of sensory-motor information, and the sensory-motor performance of organisms. Strongly interdisciplinary, the strength of this research derives, to a great extent, from a long-standing research collaboration between members of different groups.

Computation

A particularly strong and fertile interaction exists between the Artificial Intelligence Laboratory and the Department of Brain and Cognitive Sciences. In these laboratories, rapid progress is being made in understanding vision and motor control at several levels of analysis: theoretical, computational, and psychophysical. In addition to theoretical work addressing problems that any vision system must solve, there is complementary experimental work on the electrophysiology of visual cells at various relay stations, and on the development of patterned vision and stereopsis.

Work on motor control is also strongly interdisciplinary and involves faculty members from the Department, Mechanical Engineering, and the Artificial Intelligence Laboratory. Basic research activities include the relationships between multiple sensory inputs (e.g., visual, tactile, vestibular) and complex motor outputs (e.g., eye-head coordination, posture, locomotion, and arm trajectory formation). Application of research
includes development of prostheses and construction of robotic hands and arms.

Cognition

Cognitive science is the study of intelligent biological systems as exemplified principally by the human brain. The focus is on the development and function of its systems and modular parts, at a level of description more global than that of work in neuroscience but overlapping with systems neuroscience and especially with computational approaches to vision and motor control. The three main features of research in the Department are also the basis for graduate training: language, knowledge representation (including reasoning), and visual information processing.

EDUCATION

The Department's graduate program has been restructured to provide students with expertise in one of the areas of focus described above and competence in at least one other area. Specializations include molecular neurobiology, neuroanatomy, neurophysiology, neuropharmacology, neural development, neuropsychology, visual and motor psychophysics, computational approaches to neuroscience, language, knowledge representation, and visual information processing.

Two proposals for funding of National Institutes of Health training grants for graduate study were submitted this year and received outstanding scores, which represent a vote of confidence in the value of our graduate program and the scholarly activities of our faculty. Funding is effective in FY'88.

This year forty-six graduate students were enrolled in our program.

The Department also has several roles in undergraduate education. It is the home department for the undergraduate major in cognitive science, initiated in September 1982 by interested faculty from the fields of psychology, linguistics, philosophy, and artificial intelligence. Psychology faculty in the Department continue to offer a range of undergraduate subjects that students take as electives and to fulfill some of the humanities and social science requirements, including the concentration requirement. Additionally, there are many opportunities for undergraduate students to become involved in laboratory research projects in the various fields represented in the Department.

FACULTY AND STAFF

I am pleased to note the following new appointments to the faculty this year: Dr. Ellen Hildreth, Assistant Professor of Vision Science; Dr. Mriganka Sur, Associate Professor of Neuroscience; Dr. Christopher Atkeson, Assistant Professor of Motor Control; Dr. Richard Andersen, Associate Professor of Neuroscience; Dr. Arthur Lander, Assistant Professor of Molecular Neurobiology; Dr. Edward Adelson, Associate Professor of Visual Sciences, joint with the Department of Architecture (Media Laboratory); Dr. Marc Raibert, Associate Professor of Motor Control, joint with the Department of Electrical Engineering and Computer Science (Artificial Intelligence Laboratory).

The primary appointment of Dr. Richard Wurtman, Professor of Neuropharmacology, was transferred to the Department of Brain and Cognitive Sciences from the Department of Applied Biological Sciences, effective July 1, 1987.

Ms. Andrea Hatch was appointed to the staff as Assistant Administrative Officer in July 1986.

EMILIO BIZZI, M.D.
Department Head
Clinical Research Center

The Clinical Research Center (CRC) was established in 1964 with a grant from the National Institutes of Health (NIH) to provide a facility in which the Massachusetts Institute of Technology (MIT) investigators and their collaborators could apply the Institute's expertise in basic biochemical and biophysical mechanisms to the analysis of normal and pathologic processes in humans. Although MIT did not, and still does not, administer a regular teaching hospital to which its CRC might be attached, it was anticipated that a large enough number of qualified physicians from MIT's faculty and staff would become involved in the CRC's activities to enable it to take responsibility for all but acutely-ill subjects.

For most of its history, the CRC was administered within a single MIT department, Nutrition and Food Science, (or later, Applied Biological Sciences). Two years ago it became an independent entity within the School of Science, and this past year it was incorporated within the Whitaker College, reporting to the Head of the Whitaker College, Professor Emilio Bizzi and to Professor Kenneth Smith, Associate Provost and Principal Investigator of the CRC's NIH grant.

Scientists and physicians authorized to carry out research protocols using the CRC's facilities, once these protocols have been approved by MIT's Committee on the Use of Humans as Experimental Subjects (COUHES), include: MIT professors; senior research scientists who work exclusively at MIT; and those who also have appointments in local medical institutions.

During the past year, most of the research activities of the CRC have continued to be associated with three clinical areas, and to involve three groups of scientists each led by a senior professor. These areas are: Nutrition/metabolism (Professor Vernon R. Young) - an area in which the CRC constitutes the major locus of MIT's activity and one that is a traditional component of clinical research centers; Neurochemistry/neuropsychopharmacology (Professor Richard J. Wurtman) - studies on the effects of drugs, foods and hormones on brain composition and behavior, and studies on biologic rhythms in sleep and hormone secretion; and Human neuropsychology (Professor Suzanne Corkin) - focusing on the effects of diseases on cognitive and related brain functions and on genetic and other mechanism causing neurodegenerative disorders (like Alzheimer's disease). Groups collaborate on multidisciplinary projects, e.g. Obesity; Depression; Alzheimer's disease. Moreover, numerous collaborative studies involve both an MIT professor and investigators at an outside hospital or research laboratory.

Besides these three established programs, CRC investigators are now initiating research programs involving development of biomedical instrumentation, and the analysis of human autonomic functions (e.g., the contribution of the sympathetic and parasympathetic systems in generating particular electrical frequencies detected by the electrocardiogram). Such projects are especially germane to an institution with the resources of MIT. There is also the possibility that a consortium of MIT investigators active in immunology and molecular biology will develop an outpatient research program at the CRC on Acquired Immune Deficiency Syndrome (AIDS).

The uniqueness of the CRC relates to the fact that it is MIT's sole locus for carrying out investigations which require the use of medical procedures; for example, venepuncture; special diets; nutritional balance studies; hormone or drug infusions; and frequent examinations or monitoring over a prolonged period. The CRC also houses laboratories for quantifying behavioral and cognitive functions, making on-line measurements of elective nutrient intake, and developing new devices for measuring particular physiological parameters.

Bed utilization at the CRC has averaged 65.1 percent over the past year resulting in a total of 2757 inpatient days. The reduction in bed utilization reflects both an increase in the number of protocols using single-day admissions, and the termination of the Clinical Nutrition Training Grant. There were a total of 869 visits to the CRC's outpatient facilities.

The CRC is administered by a Director, (Professor Richard J. Wurtman), an Associate Director (William Abend, M.D.); a Laboratory Director (Professor Vernon R. Young); and five Assistant Directors (Benjamin Caballero, M.D., William H. Dietz, M.D., Ph.D., Naomi K. Fukagawa, M.D., Ph.D., Robert A. Hoerr, M.D., Ph.D. and Dermot A. O'Rourke, M.D.). The Assistant Directors are all young physicians who have completed residency training in medical specialties (medicine; neurology; psychiatry; and pediatrics) and have also had advanced research training, usually leading to a Ph.D. degree. Their appointment as Assistant Director allows them both to cultivate their own research interests at an important early stage in their career and to serve the CRC (for example, facilitating the conduct of clinical research by other MIT faculty who lack medical training).
The CRC Advisory Committee continues to meet monthly to advise on the operations of the CRC and to review protocols for scientific merit. Its Sub-Committee on Medical Standards also meets on a monthly basis and has special responsibility for the medical oversight of the CRC. Three new members have joined the Advisory Committee this past year. They are Dr. Ronald Arky, Chief of Medicine at The Mount Auburn Hospital; Dr. Verne Caviness, Professor of Neurology at Harvard Medical School; and Dr. Beverly Chew, CRC Biostatistician, who reviews the statistical design of all protocols before they can be submitted to the Advisory Committee.

The CRC has continued to provide training for physicians who are participating in fellowship programs at MIT. These physicians have utilized the CRC facilities to initiate research protocols and to participate in ongoing projects supervised by senior investigators and faculty. There were six graduate students and 14 postdoctoral fellows from the departments of Applied Biological Sciences, Brain and Cognitive Science, and Whitaker College and MIT Harvard Division of Health Science and Technology. At the undergraduate level seven UROP students participated in clinical research projects with physician preceptors and faculty supervisors.

Two weekly Seminar Series open to the MIT community sponsored by the CRC were held during the academic year. The series in the fall of 1986 was on "Aging" and the topic for the spring 1987 series on "Age-Related Neurological Diseases".

The CRC was also awarded, during this past year, extensive facilities for the Gas Chromatograph Mass Spectrometer (GCMS) analysis of biologically-active chemicals including those containing stable isotopes useful for kinetic studies. A CRC GCMS Laboratory will be operational during the 1987/88 academic year.

RESEARCH ACTIVITIES

NUTRITION AND METABOLISM

During the past year the CRC's Nutrition-Metabolism group under Professor Vernon R. Young has continued to give major focus to examining the regulation and quantitative aspects of amino acid metabolism in adult human subjects of varying age. These investigations utilize stable (non-radioactive) isotope tracers which can be safely and repeatedly be administered to human subjects; the CRC is recognized worldwide as a leader in this type of study. This research explores the impact of the diet, and of aging, on human amino acid metabolism, with particular reference to anabolic actions of insulin and to the changes in body composition that occur with advancing with old age.

Major highlights of this research have included the following:

1) A new approach has been developed for estimating the kinetics of amino acid metabolism under varying conditions of amino acid intake. These studies have altered estimations of the amounts of amino acids required for health maintenance.

2) New insights have been gained about the regulation of methionine metabolism in humans.

3) The role of the so-called nutritionally dispensable (non-essential) amino acids in human metabolism has been further clarified, particularly with respect the the regulation of protein biosynthesis in vivo. These studies are the first to demonstrate product feedback regulation of proline synthesis in the intact human subject. From this research we postulate that in adverse conditions (e.g. severe trauma) proline becomes a conditionally-essential amino acid, and should thus be included in amino acid mixtures designed for nutritional support of hospitalized patients.

4) Changes in the sensitivity of peripheral tissues (e.g., muscle) to the effects of insulin on amino acid metabolism may account for the erosion of body protein mass with advancing adult age. This loss of protein may contribute to age-related declines in ability to withstand unfavorable stresses, like physical trauma and infection.

5) New mathematical models are being developed to improve our understanding of the actions of the liver and intestines in the utilization of meal-derived amino acids. This research which combines compartmental modelling procedures with the stable isotope tracer techniques established at the CRC, has resulted in a more precise assessment of the way by which the major body organs integrate amino acid metabolism and achieve homeostasis under various pathophysiological states.
Obesity and Eating Disorders

Two studies of energy expenditure in obese and nonobese adolescents were conducted by Dr. William H. Dietz and his associates to determine the role of energy expenditure in adolescent obesity. In the first study, body composition, basal metabolic rate, and total daily energy expenditure were measured in adolescent boys and girls. Body composition was measured by isotope dilution of H$_2^{18}$O. Basal metabolic rate (BMR) was measured by open circuit indirect calorimetry with the ventilated hood technique. Total daily energy expenditure (TDEE) was measured over a two week period using the doubly labeled water method. (This method permits long term measurements of energy expenditure under free living conditions). Comparisons of energy expenditure were made on the basis of fat free mass (FFM). The relationship of fat distribution to glucose tolerance was examined in this same population. The waist:hip ratio (WHR) was used to characterize fat distribution. The correlation between fat distribution and the glucose and insulin response to a two-hour glucose tolerance test was measured. In the second study, metabolic and hormonal responses to two weeks of carbohydrate overfeeding were measured in 13 obese and nonobese adolescents. Energy intake on the maintenance diet was 1.5 * basal energy expenditure (BEE). During overfeeding energy intake was 2.5 * BEE.

The first study failed to show any differences in BMR or TDEE, expressed per kg of FFM, among obese and nonobese adolescents. These results indicate that the already-obese adolescent does not have a reduced energy expenditure. WHR was highly correlated with parameters of the glucose tolerance test. Thus, WHR in adolescents does not appear to be an independent predictor of the risk factors associated with abnormal glucose tolerance and hyperinsulinemia.

The metabolic and hormonal responses to two weeks of overfeeding were similar among obese and nonobese adolescents. Weight gain was similar in both groups. BMR increased similarly. There was no difference in TEF among obese and nonobese. TEF did not change in either group with overfeeding. The energy cost of activity was highly variable among individuals but did not differ among the obese and nonobese. TDEE expressed per kg FFM did not differ among obese and nonobese. These results suggest that a blunted thermogenic response to short term overfeeding is not characteristic of adolescent obesity and that differences in response to overfeeding appear to be mediated by changes in activity.

1) A pilot study on Seasonal Affective Disorder (SAD) was completed by Dr. Judith H. Wurtman and Dr. Dermot A. O'Rourke, and a second study begun (these subjects manifest a profound carbohydrate craving when they are depressed, but not when in remission). The first study monitored seasonal changes in food intake and depression among subjects studied at the CRC during the fall and winter (when they were depressed) and in the spring (when they were in remission). In addition, during the winter, subjects were treated with D-Fenfluramine, a drug that increases serotoninergic neurotransmission, or a placebo, and subjects were monitored in the CRC to see what effect the drug had on food intake and mood. A second, similar study on the effects of the drug on mood, food intake and measures of performance in SADS patients is currently being carried out. The subjects include the group studied during 1985-86 and an additional 20 new subjects.

2) In the late spring and summer of 1986, a study was begun on the Premenstrual Syndrome (PMS). Since many of the symptoms of this disorder are based on self-reports than direct measurements, we are measuring, on inpatients, such symptoms such as changes in food intake during the changes in diurnal patterns of gonadal hormones, prolactin and melatonin (this last hormone has not yet been measured in relation to this disorder; its measurement requires 24-hour blood collections). Moreover, we are testing the effect of D-fenfluramine on the excessive appetite and mood swings associated with PMS. To date, we have completed a baseline study of the changes in food intake, mood and hormone levels with 10 women who do not suffer from PMS, and have begun to study women who have severe symptoms of this disorder.

NEUROCHEMISTRY

1) A study on the effects of age on nutrient choice and on behavioral responses to nutrient intake was completed by Drs. Harris Lieberman, Judith Wurtman and Professor Richard Wurtman. This study involved monitoring food choices, activity and mood states in 40 elderly adults and 40 young adults. It also measured the effects of protein and carbohydrate ingestion in the early and late part of the day on subsequent mood and performance tasks. The data are in the process of being analyzed; a preliminary summary of the data was presented at the NIH in August.

2) In studies performed on two consecutive years it showed that the severe exercise involved in running the Boston Marathon markedly depressed (by almost 50%) plasma choline levels to levels never before observed in normal humans. Proposed follow-up studies will explore the possible consequences of these changes for cholinergic neurotransmission.
3) Oral administration of CDP-choline (cytidyl-diphosphocholine), which is widely used as a drug, in Europe and Japan, to treat cerebral disturbances associated with head injury and stroke, was found to elevate plasma levels of both choline and cytidine. Moreover, these two compounds were shown, in model in vitro studies, to interact in accelerating the synthesis of membrane phosphatides.

NEUROPSYCHOLOGY

During the past year, members of the Behavioral Neuroscience Laboratory directed by Professor Suzanne Corkin and Dr. John H. Growdon have investigated memory, visuospatial, and motor deficits in a variety of subject populations.

1) Investigations of global amnesia have sought to identify and characterize impaired memory functions. Several of these studies have examined a patient whose amnesia followed a bilateral medial temporal-lobe resection, and a patient with Korsakoff's syndrome. Both demonstrated item-specific, longlasting, normal perceptual skill for reading words that appeared through a slowly-clearing mask of visual noise, but sub-normal skill for reading similarly presented nonwords. This suggests that the perceptual skills which can be learned despite amnesia are founded on the acquisition of specific perceptual knowledge, and that the kind of knowledge is linked to the perceptual demands of the particular task. Other studies examined stem-completion priming, in which subjects who are exposed to target words subsequently tend to reproduce the target words when asked to complete three-letter stems; prior studies had shown that amnesic subjects show normal priming effects. The present study investigated the duration, task, and neural characteristics of priming in a patient whose amnesia followed a bilateral medical temporal-lobe resection, and in two patients who had undergone complete forebrain commissurotomy. Results suggest that the priming mediated by nonlimbic structures does not depend upon the integrity of cerebral commissures. Finally, mirror tracing was examined in patients with global amnesia or Alzheimer's disease, and in control subjects. Our observations indicate that fact and skill learning rely upon independent neural substrates.

2) An ongoing longitudinal study of Alzheimer's disease (AD) has the long-term goal of defining and characterizing disease subgroups. A preliminary report examined the dissociation of visual capacities in AD, at different points in the course of the disease. Subsequent work has found suggested evidence that age of the disease at its onset, separates patients into subgroups. A separate study used the Hukok Logical Thinking Matrices Test to measure reasoning ability nonverbally and independently of visual discrimination factors. Patients with Parkinson's disease without dementia, cingulotomy, global amnesia, unilateral penetrating head injury, or left hemispherectomy, scored normally on the Hukok test. In contrast, AD patients (N = 17) performed poorly, and their performance correlated negatively with BDS scores. The findings suggest that local reasoning skills are among the cognitive functions to be disrupted early in the course of AD.

RICHARD J. WURTMAN
INTRODUCTION

In the two years since the appointment of MIT's first Dean for Undergraduate Education, ODUE effort has focussed on four objectives:

- Achieving a viable and strong Committee on the Undergraduate Program;
- Establishing an Institute-wide sense of attention to and emphasis on the undergraduate academic program;
- Forging from several separate activities a more integrated and identifiable Office of Undergraduate Education to give stronger and often times new support to departmental and faculty teaching enterprises; and
- Providing leadership to an Institute-wide review of the current undergraduate academic program.

Progress toward these objectives has been steady and encouraging. But, there is a long, long way to go. ODUE is just beginning to approach the large arena of issues surrounding educational space allocation, renovation, and new construction. The Dean's first round of recommendations to the Provost for appointments of faculty to teaching chairs is now underway. CUP will experience a 50% turnover in membership going into AY 87/88. This will challenge the ability of the Dean and CUP to maintain momentum and trajectory at just the moment when the toughest issues must be broached: ones concerning the first year academic program and others concerning the need to rebalance general education and degree requirements. In the curriculum support area, the science-core departments are ready for serious attention and partnership with ODUE. At the same time, the School of Engineering will be undertaking a new "Contexts" initiative.

The current mission of ODUE is simply stated:

- To address with the academic school deans the obstacles and discouragements faculty and departments identify as impediments to serious dedication to high quality teaching, advising and other forms of interaction with undergraduates.
- To promote a climate of "Why not?" and an excitement for experimentation and possibility.
- To promote and guide Institute-wide review of academic program, educational content and rationale, balances of emphasis between research and instructional activities and between undergraduate and advanced education activities. The most obvious manifestation of review is the interlocking array of school, Institute, and departmental committees now underway. Quieter efforts and in different formats and schema must also take place, ranging to the individual faculty member -- who must undertake personal internal review of his/her professional dedication and goals within this institution.

There are two fundamental issues underlying this mission. The first pertains to the content, form, and character of the undergraduate academic program. The faculty seeks to regain broadly-based agreement about the purpose of the undergraduate academic program and its intended audience. The second issue is that of achieving a proper balance of faculty commitments between research enterprises, including postdoctoral education and graduate education, on the one hand, and undergraduate education, including non-classroom encounters, on the other. Both of these issues will require as much as a decade or more to address and are not amenable to curricular decisions or to academic legislation. And, both of which are too simple in that they treat the symptoms, not the source of them. The nub of things is MIT's own culture. It is here that the Institute's strengths and uniqueness lie. And it is here that the viscosity surrounding change may be high. Our task is to try.

MARGARET L.A. MACVICAR
The Committee on the Undergraduate Program chaired by the Dean for Undergraduate Education, experienced an extremely busy and productive year. It set as its goal the exploration of the possibilities for an undergraduate program whose general features provide each MIT undergraduate -- in today's context -- with attitudes, habits of mind, and approaches to learning that ensure a lifetime of technical competence, social contribution, and personal fulfillment. CUP's immediate priority was the development of a framework for presenting a coherent picture of the proposed undergraduate requirements -i.e., MIT's general education component- to the Community. The Committee also planned to charge a small group to examine the structure of the freshman year, with an eye to redesigning it.

During the summer, an intensive week-long meeting produced both a tentative framework and practical embodiment for the General Institute Requirements, pulling together threads from the reports and deliberations of the HASS and Science committees and the Engineering Commission as well as a sharper focus on the freshman year academic experience.

In the fall, CUP launched the reports of the Institute Committee on the Humanities, Arts, and Social Sciences Requirements (chaired by Professor Pauline Maier); the School of Science Education Committee (chaired by Professor Robert Silbey) which reviewed the science and mathematics component of the current General Institute Requirements; and the Commission on Engineering Undergraduate Education (chaired by Professor Jack Kerrebrock) which addressed the relationship of the Institute requirements and other features of the core undergraduate educational experience to engineering degree programs. The mailing of these reports to the Faculty began a process of broad discussion of the objectives and proposals contained in reports.

In January, an intensive three-day meeting was held to prepare CUP for making a statement to the Faculty about the specific directions MIT should take, and is exploring, in its undergraduate educational program. The Committee invited several guests to participate in discussions on "Contexts" courses; the Keniston integrative education "design team"; the freshman year; the Laboratory Requirement; the science core curriculum; the Chemistry, Mathematics, and Physics Requirements; and the HASS proposal.

CUP presented two proposals for a Faculty vote: a motion to adjust the Humanities, Arts, and Social Sciences (HASS) Component of the General Institute Requirements and a proposal to permit a minor in HASS. The HASS Requirement proposal is "designed to promote increased breadth in a manner that complements the concentration component and to provide a more structured and intellectually coherent overall HASS Requirement." In response to Faculty and student concerns, the vote on the HASS proposal was postponed until May, and CUP organized a series of Institute-wide events for debate and review of controversial aspects of the proposal. An amended version was then put forth and approved by a Faculty vote.

The proposal for an optional Minor in HASS for any student is a response "to needs expressed by persons in the School of Engineering for an experience in HASS which is more structured and more serious than that which most engineering undergraduates now have and by some faculty in SHSS for a larger constituency within the undergraduate engineering student body with a serious commitment to education in HASS." The proposal was also approved by a Faculty vote in May.

During the year, CUP: 1) endorsed the Dean for Undergraduate Education's plan to charge a committee, chaired by Professor Kenneth Manning, to examine the freshman year; 2) charged a working group, chaired by Kenneth Keniston, to follow up on ideas from the Marx report on an integrative curriculum in the liberal arts and "to consider and recommend to the CUP, for its approval, a proposed set of institutional/structural features and changes constituting an educational experiment aimed at promoting the development of an integrative education for MIT undergraduates" [the minor proposal was the first product of the Keniston effort]; 3) approved three proposals for "Contexts" courses transmitted by the School of Engineering Interschool Working Group on Contexts Subjects, chaired by Professor Elias Gyftopoulos; 4) discussed restructuring the Institute Laboratory Requirement to be based in departments; and 5) accepted and endorsed the report presented by Professor Leon Trilling on the Integrated Studies Program's proposals for future development and renewed ISP's experimental license for three years.
Throughout the year, CUP held discussions on the math-physics linking initiative, changes in admission procedures at MIT, linking the Admissions Office with first-year instructors and providing more communication of admissions data, the three alternative programs (ESG, ISP, and the Concourse), and student perspectives on educational policy and reform.

CUP expects to continue its efforts in many of these same areas during the upcoming year.

Professor James Munkres, Pauline Maier, and Ed Roberts completed their terms. Student members Jonathan Gruber and Carey Rappaport finished their studies and graduated. David Wiley, Head of UASO, Mr. Michael Behnke, Director of Admissions, and Mr. Bryan Moser, UAP, were Guests of CUP for AY 87.

LAURA B. MERSKEY
Secretary to CUP
Concourse, the Undergraduate Research Opportunities Program (UROP), the Office of the Writing Requirement, and the Office of Curriculum Support comprise the embryonic programmatic arm of the Office of the Dean for Undergraduate Education. With adjacent office space in Building 20, these three offices have during the course of a year begun to integrate into one office. As common policies evolve in the next year, and future space arrangements follow function, this consolidation will be strengthened. In the coming year the office will combine finances, keeping separate program accounts, and operate from a single budget.

The Office of the Dean for Undergraduate Education (ODUE) is represented by staff of its programmatic office on a variety of Institute committees: the Committee on Curriculum, the Committee on Admissions and Financial Aid, the IAP Policy Committee, the R/O Week Advisory Committee, the Colloquium Committee, the Committee on the Writing Requirement, the Undergraduate Student Wage Review Committee, and the Ad Hoc Committee on Course Evaluation.

The sections which follow discuss the major program areas of each section within the Office for Undergraduate Education: Concourse, Curriculum Support, UROP, and the Writing Requirement. Following these summaries is a brief summary of staff activity.

Concourse

Concourse is an alternative program for freshman year which covers all of the standard curricula, its structure following the core curriculum in terms of lectures, recitations, problem sets, and quizzes. Courses are collaboratively planned although separately taught. The difference lies in the class size (limited to 64 students) and the intimacy the students gain with their professors, tutors, and each other in respect to their work. The goal of the program is to put everyone on such close terms that students not only help one another but feel no constraints about consulting professors and tutors. At the same time the faculty finds it easier to teach familiairs rather than strangers -- tensions are less.

A) Student Statistics:

Sixty-four students enrolled in Concourse for fall term. Enrollment for women reached the highest level, 36 in our sixteen year history. There were 22 minority students equally divided between men and women. The spring semester had 69 students of which 24 were women and 14 minority students, with minority enrollment again divided equally between men and women.

Sophomores who went through Concourse for the entire freshman year show no academic differences from their counterparts enrolled in the regular undergraduate curriculum. Statistics are exactly the same.

The disciplines entered by last year's Concourse students are these: 32 in departments within the School of Engineering, 13 in departments within the School of Science, one in the School of Architecture and Planning, and one remained undesignated.

B) Faculty and Staff:

The extensive role undergraduates play as teaching assistants to a dedicated and experienced faculty plays a vital role in the success of the program. It is worth noting that all Concourse core faculty have been recognized for teaching excellence by awards or prizes at some time in their careers. Members of the Concourse faculty for 1986-87 were: Professor Jerome Y. Lettvin, Departments of Biology and Electrical Engineering and Computer Science; Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Judah L. Schwartz, School of Engineering; Professor Kenneth R. Manning, Director of the Writing Program; Professor Emeritus Irving Kaplan, Department of Nuclear Engineering; Dr. Ross L. Finney and Ms. Kathryn Lesh, Department of Mathematics; Dr. George Plockin, Research Laboratory of Electronics; Dr. James Adams, Department of Humanities; and Dr. Paul Josephson, Department of Political Science. Ten MIT undergraduates were employed as teaching assistants each term to run recitations and evening tutorials in chemistry, calculus, physics, and differential equations.

Professors Jerome Lettvin and the late David Adler, Co-directors, and Ms. Cheryl Butters, Program Administrator, were overseers for the program.
C) Academic Developments:

In Concourse Chemistry the ideas of modern materials science are used as a tool to teach freshman chemistry. The result is a series of bridges or connections to the other sciences and the arts, including history, demonstrating the significance of chemistry and permitting further intellectual explorations and perspective. This approach also includes coordination with the other courses and sharing and reinforcement of the ideas that come from them, e.g. consider atomic structure; crystallography and molecular geometry; or, steelmaking. Concourse chemistry is identical neither to 5.11 Principles of Chemical Science or to 3.091 Introduction to Solid-State Chemistry but contains the essential elements of both, and may serve, as a prerequisite, for example, for 5.12 Organic Chemistry or any course which has 3.091 as prerequisite. The small size and more extended personal contact involved in Concourse make possible such a treatment of freshman chemistry.

During the 1986-87 academic year, Concourse students and faculty continued the development of software to support the teaching and learning of introductory physics. These efforts focused on two areas of conceptual difficulty, scalar and vector fields, and normal modes of oscillations. Traditionally, these concepts are introduced in the freshman year, usually via their formal mathematical description. It has been our experience that it takes a long time for ideas to become part of the analytic toolkit students carry. Mindful of this, we designed and complemented, with support from Project Athena, two software environments that allow students to work flexibly, and, we hope, intuitively, with such ideas.

In addition, the Concourse class that enters in September 1987 will use an Athena-based modification of Common Ground, a computer conferencing system, developed at Harvard's Educational Technology Center. This system, whose design has been optimized for simplicity and ease of use, will expand that communication among students, teaching assistants, and faculty which is one of Concourse's most important features.

We spend some time in 18.01 Calculus on the physical problems from which calculus developed and also on the current uses in applied fields. We show the critical role it plays in judging various approximation methods. In pacing it with physics, we use common instruction in graphing, root-finding, and solving first order differential equations by computer display. These are particularly helpful in dealing with the concepts of oscillators that occupy equally the work in 18.03 Differential Equations and 8.02 Physics II.

Humanities is devoted in the first term to a history of ideas in science with special emphasis on the line that extends from Greek science to the Age of Enlightenment. This treatment we believe is the proper way of linking the notions that develop in common between abstractions in mathematics and observations on the natural world.

One of the most vivid consequences of Concourse is the personal growth of undergraduate assistants as teachers and guides. We believe more undergraduates should be employed in this way because, in some not easily measurable fashion, they become distinctly better in their other work as well.

Curriculum Support

Efforts in this section were principally the responsibility of assistant dean Margaret S. Richardson who joined ODUE on a full time basis in July 1986. As mentioned in last year's report, this effort is dedicated to catalyzing and supporting educational awareness, communication and activities throughout the Institute. Activities this year, most of which are described below, have been quite successful.

A) Coordination and support of collaborative activities between mathematics and physics:

This was the second full year of a cooperative effort undertaken by the mathematics and physics departments, with assistance from this office, based on pairing freshman recitation instructors with a common population of students. (A brief description of the history and goals of "linking" is contained in last year's Report.) This year the objective was to strengthen these connections and take advantage of the special nature of the experiment to provide a source of information about the freshman year experience.

During the fall term, in addition to the linking of recitation sections between the subjects, a pilot effort was attempted to address the differences in the mathematics preparation of students in 8.01 Physics I. Students were assigned to 8.01 lecture sections and to many 8.01 recitations (including the linked sections) based on their registration in mathematics. Thus the large number of 18.02 Calculus-level students enrolled in 8.01 were assigned to a different lecture section--and, in many cases, to different recitation sections--than those
students with weaker mathematics backgrounds. The effort was accompanied by regular discussions between lecturers in 18.01 Calculus and 8.01 and the linked math and physics recitation instructors, by frequent interviews with the linked instructors throughout the term, and by interviews of a random sampling of freshmen throughout the year. These activities greatly increased the departments’ appreciation of what each was trying to teach and catalyzed discussion of the relationship between the subjects and the expectations placed on students. The roles played by the recitation section and the section instructor were a central focus of these discussions; it is expected that the next few terms will see increased attention to this issue.

Because of the generally enthusiastic response to this office’s endeavors last fall and increased appreciation of the impact of students’ mathematics background on their performance in physics, all 8.01 recitation section assignments will be made based on student enrollments in freshman calculus in the coming fall term. Linked sections will be created between 8.012 and 18.02 as well.

In the spring 1987 term 8.02 Physics II and 18.02 recitation sections were linked only to the extent that students signed up to be in such sections. Since only 70 students opted to join sections that promised to address the difficult concepts in both subjects, it is again clear that faculty and students are more enthusiastic about the utility of the math-physics coupling in the first, rather than second, term.

Faculty continue to be enthusiastic about the potential of a more integrated and collaborative freshman year program. Yet many feel they cannot devote the additional time required to develop a more creative teaching style. Our role has been to nurture the excitement of interested departments and instructors and provide the resources and encouragement for carrying out their ideas. Although it has been frustrating at times, rewarding at others, it is clear progress has been made. A level of enthusiasm about the potential for improvement in the freshman program exists that was not so apparent just a year ago.

B) Other activities in support of the freshman program:

This office continued its responsibility for supporting the regular meetings of the faculty and administrators associated with the freshman program, the "Core Curriculum Group," chaired by Dean of Science Gene M. Brown.

As a result of the general concern expressed by faculty about the lack of laboratory or other experimental experiences in the freshman curriculum, Dean Brown asked a small group of faculty to study the situation. This office played a major role in the production of the report issued earlier this year.

In association with Professor Benson Snyder (see next), this office coordinated a year long series of open-ended interviews with approximately 50 freshmen selected at random who were interviewed by 10 staff members, all of whom had a long standing involvement with the freshman program. Transcripts of these interviews should provide a picture of students’ freshman year academic experiences. The team of freshman interviewers--staff from the core undergraduate offices, the UASO, the special freshman programs, and the ODUE--have had a unique opportunity to share perspectives.

At the request of Professor Arthur Mattuck of the Department of Mathematics this office coordinated a series of meetings between faculty in charge of the core physics and mathematics subjects and faculty in the School of Engineering who teach the major sophomore engineering subjects. The meetings provided an opportunity for the engineering faculty to voice specific concerns about student preparedness in upper level subjects that they felt were due to freshman year curricular or teaching deficiencies. Syllabi were swapped (in some instances for the first time in 20 years), and there was general consensus that there be meetings of this kind in the future.

Together with staff in the UASO, this office worked to offer new R/O Week activities designed to expose incoming freshmen to the wide range of research opportunities taking place at MIT. The seven offerings during fall 1986 "Academic Explorations" were well received by freshmen, and the 1987 R/O Week should see an expansion of this activity.

With regard to class scheduling and support to lecturers and recitation instructors, this office has attempted to bridge a communication gap between the faculty and some Institute support facilities. Our involvement has included a review of the current status of the evening academic schedule (i.e., evening quizzes scheduled in conflict with evening subjects), a convening of the users of the large lecture halls to review the current schedule, and beginning efforts to support these same users in the classroom (e.g., responding to complaints about blackboards, classroom disruptions, and so on).
Coordination with Graphic Arts made possible the reestablishment of student photo distribution to both freshman recitation instructors and upperclass departments and instructors.

The Undergraduate Seminar STS S08, "Student Perspectives on Educational Policy and Reform," was offered both terms this year. The seminar is intended to provide a springboard for students who wish to continue their interest in educational issues by acquainting them with many of the people, problems and possibilities at MIT. This office was pleased that students involved during the fall produced a substantial report ("From the Outside Looking In: Students View Educational Reform") that was presented to the Committee on the Undergraduate Program. At least four of those students have gone on to join faculty committees or participate actively in current issues.

Additional activities included: publication of the "Resource Guide for Academic Officers"; the bringing together of the departmental academic officers and administrators on a regular basis to provide the opportunity for discussion of issues of mutual concern and interest; coordinating meetings chaired by Dean MacVicar between freshman subject instructors and members of the Minority Student Issues Group to discuss issues raised in the report "Racism at MIT".

C) Studies and Intervention

Professor Benson Snyder engaged more than half of his time during the academic year 1986-87 in activities directly related to the Office of the Dean for Undergraduate Education.

Working closely with Margaret Richardson, Assistant Dean for Curriculum Support, in her efforts to effect linking in selected core recitation sections, Professor Snyder observed a number of 8.01 Physics I, 8.02 Physics II, and 18.01 Calculus lectures, recitation sections and interviewed core lecturers and instructors, other faculty, administrators and students. He also participated in the meetings convened by Dean Richardson to consider the educational and administrative issues associated with the linking effort.

This modest but potentially useful educational reform has revealed a number of underlying issues which will need to be addressed as various specific modifications in the freshman year are considered by the Committee on the Undergraduate Program and the Committee on the First Year Program.

In a related undertaking, initiated in September 1986, Dean Richardson and Professor Snyder invited a group of freshman program administrators to undertake a series of interviews with freshmen randomly selected from this year's calls. Approximately 60 subjects (5 percent of the class) have been interviewed from one to four times. The primary purpose of this effort has been to provide an accurate, reasonably representative picture of the current freshman experience. Professor Snyder, Dean Richardson and Ms. Bonnie Walters, Coordinator, Committee on the Writing Requirement, together with a subgroup of the interviewers are preparing a report on the major themes and issues that characterize the freshman educational and living experience.

Professor Snyder taught the seminar STS S08, "Student Perspectives on Educational Policy and Reform" both fall and spring semesters. This seminar had originally been offered in spring 1986 with Professors Kaysen, Snyder and Dean Richardson. the seminar's goal was to introduce the students to the recent history of educational reform at MIT and to become informed about current educational proposals.

A continuation of these and related activities are projected for the coming year. The purpose throughout has been to increase faculty and student appreciation of the problems and possibilities of estimating the educational impact of various proposals for change in the freshman year and beyond. The effort has been to raise the level of discussion above anecdote, to provide an historical frame of reference and an appreciation of the inherent complexity of educational reform at MIT.

Undergraduate Research Opportunities Program (UROP)

A growing national trend toward undergraduate participation in research continues to spur interest in MIT's now eighteen year old program. UROP associate director Norma McGavern was invited to consult with SUNY Stony Brook in October. Their undergraduate research program is now underway. Barnard College and Case Western Reserve sought guidance from UROP in the course of making their own program decisions. The University of Minnesota, having consulted with UROP two years ago about how to go about setting up an undergraduate research program, sent many of its current student participants to the first National Conference on Undergraduate Research held in spring 1987 at the University of North Carolina at Asheville.
Assistant dean for undergraduate research Jane Sherwin also attended this conference and was invited to become a member of its executive committee. The May 27, 1987 issue of the Chronicle of Higher Education discussed this enlarging national interest in the context of UROP and other program sites where MIT's program has been used as a model.

Giving recognition to the growing importance of and interest in undergraduate research, the National Science Foundation (NSF) launched its new Research Experiences for Undergraduates program in December 1986. The program is based upon concepts of undergraduate research developed and tested over the years in MIT's UROP and reflects Dean MacVicar's active role in NSF, currently as vice chair of the National Advisory Committee of Science and Engineering Education. To date, proposals have been submitted and awarded for on-site research in the Experimental Sedimentology Laboratory and the Biotechnology Process Engineering Center, with funding for more than 20 MIT undergraduates in the coming 12-month period. A third on-site proposal in the Department of Earth, Atmospheric and Planetary Sciences is pending. In addition, fourteen faculty in eight departments have requested supplemental funding to their ongoing NSF grants to cover the cost of undergraduate salaries. These supplements represent an average of $8,000 per grant to cover the costs of two students for one calendar year. Ms. Sherwin continues to assist and encourage faculty wishing to draw on the resources of this new NSF program and will submit a proposal directly to the NSF in the summer of 1987.

Two UROP efforts supplement or aid other Institute educational initiatives. As the issue of reforming humanities and social sciences requirements was being discussed, $50,000 of the annual undergraduate research budget was set aside by UROP for fiscal year 1988 to encourage UROP participation in the humanities. As of June 1987 some two-thirds of these funds were claimed by new projects in literature, history, and the arts. In another effort, the Engineering Council created a task force in the fall of 1986 to investigate the creation of an expanded industrially-funded UROP program, with Ms. McGavern as UROP's representative in that effort. Discussions are still underway and will continue during the 1987 summer.

Drawing on the resources of the coordinator of the Writing Requirement Ms. Bonnie Walters, the UROP office continues to encourage the strengthening of undergraduate writing skills through students' preparation of UROP proposals, end of term evaluations, and UROP reports. During IAP Ms. Sherwin and Ms. Walters collaborated on a two-day class on the writing of research papers. A similar effort will be scheduled in the coming year. A writing guide for undergraduate research papers is also planned.

Undergraduate researchers were once again heavily in demand as speakers and participants in a variety of Institute events. Undergraduates were invited speakers at alumni clubs in New Haven, Connecticut, and Minneapolis, Minnesota. More than 20 students participated at the request of the Resource Development Office in two of their Campus Visits program. In a third, Professor Jeremy Wolfe of the Department of Brain and Cognitive Sciences joined Ms. Linda Elkins, '87, Marc Filerman, '88, and Mark Wang, '87, in a panel discussion of the program. The 1987 Technology Day program featured presentations of Project Athena work by faculty and several of their undergraduate researchers. UROP students also participated in UROP's "How to UROP" IAP activity, an event organized by program coordinator Ms. Maureen Horgan.

The Wei UROP Award joins the list of prizes in undergraduate research, this newest prize for a student who has made "the most outstanding contribution in undergraduate research at the interface of the life sciences and engineering." It is an award made in memory of Randolph G. Wei, an avid UROPer who was to have been a graduating member of the Class of 1987. The first prize to be given went this spring to David J. Weitz, '87. The Orloff UROP Prize for outstanding physics-related research was given this fall to Mark Wang, '87. The Dean A. Horn Award, established last year, was also given for the first time to Alessandro Bocconcini, '86. Eight undergraduates were awarded Civil Engineering Traineeships. Five students received support for original engineering design from the Clapp and Poliak Engineering Design Fund, and 12 were supported by the Admiral Luis de Florez fund for work in engineering design. McCormack Awards for undergraduate research in areas relating to technology and its applications to the problems of mankind, society and the arts went to two undergraduates. Eight received support from New England Life for medically related research. This support was renewed in fall of 1987. The Class of 1972's new endowed fund for the encouragement of undergraduate research which improves the quality of life through its impact on society and/or the environment reached a principal amount of over $40,000, nearly three times the minimum goal set by the Class. Sea Grant gave awards to 19 undergraduate researchers involved in ocean and ocean-related topics. The MIT Chapter of Sigma Xi gave materials and services support to two students. Michael B. Parker, '89, and Walter Robert Sabiston, '89, were winners of this year's Eloranta Summer Research Fellowships.

UROP participation this past year was at virtually the same level as last year. The UROP wage rate of $5.50 an hour, upped a year ago to the Institute minimum wage rate level, has remained at that figure. A June 1987 rise in the Institute minimum wage to $5.75 did not instigate a
similar rise in the UROP rate, as funding demands did not allow it. Continued unrestricted support from the Lord Foundation this year helped us allow an even participation level in the face of high funding requests. The amount of wages on which UROP waived overhead was 10% higher this academic year than the previous academic year. The 1987 fiscal year total can be expected to be over $3 million.

The UROP office's computing capabilities have progressed happily, still with the consultation of student Jae Sang, '88. Mr. Sang has completed documentation of the master computer program that tracks all proposal procedures and generates statistical reports. The program will continue to evolve, but this was a milestone in that it provides a starting point for future system enhancement without the need for prior intimate knowledge of the present system. The UROP Directory was updated on computer disks for the second year, a process that has now paid off in efficient use of time. Ms. Horgan was invited to participate in Information Systems' Pilot 3 initiative to evaluate and make recommendations for a standard system of hardware and software for all MIT administrative offices. UROP's plans for next year include steps toward office networking.

Old office and student files have at last been sorted, reorganized and boxed. Ten years' worth of records will be stored in building 20 for the present. All other student records created prior to 1977 have been sent to Institute Archives. Each year UROP will send along another year's records beginning with the 1978 records in June of 1988. Current active UROP files have at last been reviewed and will be physically reorganized in the summer of 1987.

The Writing Requirement

The Committee for the Writing Requirement finds itself happily at home within the Office for Undergraduate Education in 20C-105. Integrating the work of the Committee into the larger tasks of the ODUE team has provided the background of our work this year. After years of annual moves, it is both a relief and a pleasure for our coordinator to find herself among colleagues who provide much-needed support.

The activities of the Committee follow the school year, starting with the freshman essay evaluation during R/O Week, then moving on to the judging and handling of the Phase One and Phase Two papers students submit throughout the year. Both of these efforts represent substantial time spent in counseling students about writing.

The Committee met on a monthly basis throughout most of the year, meeting more frequently during the crucial spring term. In anticipation of the Report on Phase Two the committee will present to the faculty in fall 1987 an all day meeting was held off campus in October. In February through June there was a major push to help the graduating members of the Class of 1987 satisfy the Requirement.

A) Freshman essay evaluation:

In the six years the freshman essay evaluation has been given, it has become clear that R/O Week may not be the optimal period in which to offer the test. The UASO has long felt the pressure students experience during R/O Week precludes their doing well on the evaluation. In September 1986 the freshman essay evaluation was deliberately de-emphasized by describing it as an optional test in many R/O publications. A third testing date was offered in October as a further means of minimizing stress to freshmen.

The evaluation is but one option students may use to attempt to satisfy Phase One of the Requirement, but it remains by far the most popular. The "minimizing" publicity had its effect, however. A significantly smaller number of students took the evaluation: 762, as opposed to 970 in 1986. Of the 762, 214 received a full pass, 283 a marginal pass, and 265 a not acceptable rating.

Counseling attendant upon the evaluation continues to be very heavy throughout all of September and October each year. Having conferences with freshmen about their writing early on serves them well, not only in focussing them on their writing but also in further orienting them to MIT.

B) Phase One and Phase Two papers:

The second most popular option students use to satisfy the Writing Requirement is that of submitting five-page (Phase One) and ten-page (Phase Two) papers. The Coordinator received 210 Phase One papers (61 passes, 72 marginal passes, 56 not acceptables, and 21 still to be evaluated) and 625 Phase Two papers (258 passes, 192 marginal passes, 167 not acceptables, and 8 still to be evaluated).
The higher number of Phase Two papers this year reflects those graduating seniors who waited until the March 1, 1987 deadline to submit papers to satisfy the Requirement. Over 300 papers were received between February 15 and March 1, 1987.

The process of rewriting papers appears to teach students a great deal about the writing process. Among those students who submitted their papers at the last minute were some who had to rewrite papers more than once. The resulting multitude of papers could not have been handled without the help of a small army of readers. The Writing Program, through its technical writing teachers, read many, many papers. Some 30 graduate students from the departments of Electrical Engineering and Computer Science, Chemistry, Physics and Management, as well as a number of outside readers, were also employed as readers. The graduate students often doubled as teachers, reviewing papers with students and rereading their papers. That such conferences bore results can be seen in the superb quality of many of the rewritten papers.

The experience of this and past years tells us that the problems MIT students have in writing well often results from their not spending sufficient time on their work. A relatively small number of students do have serious writing problems. The Committee hopes to address the special problems of that group in its upcoming fall report.

C) Other means of satisfying Phases One and Two:

Phase One of the Requirement can also be satisfied in two other ways: 1) by receiving a 750 or above in the College Achievement Test in English Composition with essay, or 2) by receiving a pass in 21.334 Expository Writing II for Undergraduates: English as a Second Language, 21.730 Expository Writing, or 21.732 Introduction to Technical Communication. Results for students using these options are as follows:

<table>
<thead>
<tr>
<th>Writing Subjects</th>
<th>Students Receiving 750 or Above</th>
<th>Students Receiving a Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.334</td>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td>21.730</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>21.731</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>21.732</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

Phase Two can also be satisfied by receiving a B or better as a writing grade in one of the designated technical writing cooperative subjects offered in a number of departments primarily in the School of Engineering. Approximately 300 students exercised this option. The advanced science and engineering subject 21.780 Scientific and Engineering Writing, or the English as a Second Language versions 21.339 Workshop in Writing for Science and Engineering or 21.340 Workshop in Writing for the Social Sciences and Architecture, offer another Phase Two option, one exercised by 70 students this year.

D) All-day meeting of the Requirement Committee:

The Committee has long needed to spend more time on the Requirement than a one hour monthly meeting offers. The all-day meeting in October 1986 provided that opportunity. Each segment of the Requirement was reviewed and reports were heard from Professor James Paradis (Writing Program), Ms. Norma McGavern (UROP), Professor Suzanne Flynn (English as a Second Language Program), among others. We emerged from the meeting with plans for the Fall 1987 Report as well as preliminary drafts of the surveys of faculty and students that will form part of the report.

E) IAP mini-course:

The Committee wants to encourage UROP students to turn their final reports into Phase Two submissions. The IAP mini-course presented by Ms. Walters and Ms. Sherwin suggested a format for such reports, each segment of which was reviewed with the 13 participants. Students then wrote brief introductions to their reports. The quality of their writing was excellent. This class will be repeated next year.
F) The Class of 1987 and the Requirement:

The major effort of the year was helping the graduating seniors satisfy the Writing Requirement. Despite warnings from many sources that began when they entered MIT in 1983, too many members of the Class of 1987 delayed satisfying the Requirement to the penultimate moment. The academic year began with the grim figure of over 400 seniors still needing to satisfy one--or in some cases both--phases of the Requirement. Massive publicity included advertisements in The Tech; LSC slides; posters; buttons; banners; having Registrar's statistics sent to departments; letters written to students, to advisors, departmental administrators, housemasters and fraternity presidents; even personal calls to seniors. At times it appeared that the entire MIT community involved itself in this effort. The Committee thanks everyone. In the end, not one senior failed to receive his or her degree solely because of failure to complete the Writing Requirement.

The Class of 1987 was the first class to complete the Requirement. In defense of their delay in doing so it must be noted that many departments did not offer extensive means to satisfy Phase Two (which should be satisfied within the student's major). The additional technical writing cooperative subjects now offered in courses 5, 7 and 8, as well as those projected for course 6, should enhance students' passage through the Requirement in coming years. The Committee is well along in planning to minimize crises such as those experienced this year.

G) Fall 1988--Faculty responsibility for Phase Two:

The faculty will assume primary responsibility for Phase Two in the fall of 1988. In October 1986 Provost John Deutch requested that departments name departmental Writing Requirement coordinators and submit to him their plans for assuming this responsibility.

To date few departments have carried out either task. Most of the Committee's work during the 1987-88 academic year will focus on preparing departments to take charge of Phase Two. Several departments have made progress in that direction, the Department of Mathematics in particular, by not only forming a departmental Writing Requirement Committee, but creating a subject in mathematics writing from which the Committee has received several well-written papers. In spring 1988 the Department of Management will offer an undergraduate writing subject from which papers may be submitted for Phase Two. Both of these new endeavors offer models other departments might emulate in their own planning for Phase Two.

H) Committee membership:


Since its inception in 1983, Professor Kenneth Hoffman has guided the implementation of the Writing Requirement as Committee Chair. His skilled direction and advice have been particularly useful to the Coordinator. After four busy years Professor Hoffman passes on the leadership of the Committee to Professor Tester of the Department of Chemical Engineering.

Staff of the Office for Undergraduate Education

Dean for Undergraduate Education Margaret L. A. MacVicar was a first recipient on November 6, 1986 of the Charles A. Dana Foundation Commendation for Pioneering Achievement in Higher Education. The foundation cited UROP's success as a demonstration that "determination can reshape the architecture of a major research university to make room for creative collaboration of senior faculty and undergraduate students."

Three sections of the Office for Undergraduate Education--Curriculum Support, UROP, the Writing Requirement--were grateful to have Ms. Pamela Laufenberg join the office in October as staff assistant. Ms. Laufenberg has managed a difficult assignment remarkably well, splitting her time between the three sections.
Ms. Norma McGavern, while remaining associate director of UROP, has taken responsibility for overall operations of the new consolidated office. Ms. Jane Sherwin, who joined the UROP office as assistant director in July 1986, completed her first year as assistant dean for undergraduate research, a title which more completely describes her role within UROP and the Office for Undergraduate Education. Ms. Margaret Richardson began this year in a newly created position, assistant dean for curriculum support, for which she had to define and shape many specific job functions. Having done this quite successfully, Ms. Richardson went on to give birth to a baby daughter in June 1987 and began a leave of absence planned to last until September. Ms. Richardson's activities with regard to math and physics linking will be overseen by Ms. Horgan during her absence. Activities with regard to the IAP Policy Committee will be handled in the interim by Ms. Sherwin. This taking on of several of Ms. Richardson's responsibilities will likely aid in future cooperative efforts. Ms. Richardson and Ms. McGavern in late winter jointly attended the annual American Association for Higher Education conference in Chicago.

Mr. Gregory Smith remains with UROP on a shortened part-time schedule as special projects coordinator. Ms. Dianne Brooks, promoted to Administrative Assistant in September 1986, continues to keep the office running smoothly.

Ms. Bonnie Walters has been aided admirably by student helpers Alexandra Page, '88, Kris Sheahan, '89, and Corinne Wayshak, '89. UROP staff have been assisted not only by Jae Sang, but also Sayan Chakraborty, Philip Kuhn, Dawn McKinley, Angeli Salgado, members of the Class of '89, and Teresa Lyons, '90. UROP and the Writing Requirement have both been fortunate to have the creative services of Ms. Laurie Sokolsky who has done design work for both sections.
The Annual Report of the Dean of the Graduate School (DGS) appears in two parts. The first is a pair of narrative reports by the Dean and Associate Dean. The second is a set of tables of statistical information for the Graduate School. These are presented in formats similar to those used in past years in order to facilitate comparisons over time.

DEAN OF THE GRADUATE SCHOOL

A major, and largely unanticipated, activity of the past year arose from the federal government's adoption of the Tax Reform Act of 1986. That Act altered in fundamental ways the tax status of almost all graduate students in the United States, and created in all graduate offices an unusual degree of confusion and uncertainty. A particular problem was created by the fact that the Act became effective on January 1, 1987, but detailed rules and regulations for implementation of the new tax law were not expected to be issued by the Internal Revenue Service (IRS) until many months later, and had still not been issued by the end of this past academic year.

An ad hoc committee, chaired by Dean Frank E. Perkins, was established to develop appropriate policies and procedures for dealing with the newly imposed tax status of MIT's graduate students. Among the many issues dealt with by the ad hoc committee were the following:

1. tax status of research and teaching assistant tuition scholarships;
2. withholding and reporting requirements for graduate assistant and fellowship stipends;
3. special requirements for withholding on the fellowship stipends of non-resident alien graduate students;
4. applicability of the Social Security Tax and Massachusetts Income Tax to graduate students;
5. "grandfathering" under the previous tax law of graduate students who were appointed prior to August 17, 1986; and
6. adjustment of research and teaching assistant stipends to compensate for the impact of the new tax liabilities.

An advisory memorandum was issued by Dean Perkins to all graduate students in January and an open forum on MIT's interpretation of and response to the new tax law was conducted by the ad hoc committee in February. Since then, additional information and interpretations have continued to be developed, and the Office of the Dean of the Graduate School has become a central source of information for graduate students with tax questions.

Last year's report identified the growth of graduate student enrollment as an issue of concern and attention. This concern was conveyed in various ways to department heads and academic deans in those areas where the rate of growth appeared to be unusually large. As a result of these efforts, the graduate enrollment growth of about three percent per year, which had been experienced in recent years, was noticeably reduced to just over one percent in the past year; however, the total enrollment of regular graduate students did continue its inexorable climb toward the 5,000 mark (actual enrollment equaled 4979 students; see Table I for more detail) and exceeded that mark if special students (i.e., those not working toward a degree) were included. The ratio of graduate to undergraduate students increased from last year's figure of 1.08 to a new high of 1.13, driven both by the small increase in graduate enrollment and a significant, planned decrease in undergraduate enrollment. The question of whether more explicit steps should be taken to manage the size of the graduate student population remains on our agenda for further consideration.

The Graduate Student Council (GSC) continued to expand the scope and importance of its role in graduate student life at MIT. A subcommittee of the GSC addressed the failure of current housing policy to provide an adequate number of spaces to new graduate students, and developed a proposed new policy which could increase the number of spaces available in Institute housing for new students from the current value of 18 percent of the incoming class to 36 percent. With help from the ODGS and the Office of the Dean for
provides a useful data base of facts, attitudes, and opinions concerning graduate
wording of doctoral diplomas was presented to the Faculty Policy Committee (FPC) for its
The statement on "Graduate Student Rights and Responsibilities," which was undertaken
the Cambridge-Boston area and the shortage of Institute housing for graduate students.
their experience at MIT; however, specific problems in particular departments were
identified along with continued expressions of concern over the high cost of living in
the third year of its 5-year initial approval; approval of a Doctoral Program in Speech and
Review of Academic Actions of the CGSP, was completed and endorsed by the full CGSP. This important document establishes principles to guide the
relationships between graduate students and faculty, and will, it is hoped, clarify the
expectations which each should have for the other. The statement will be added to the

The CGSP reviewed a number of programs and proposals including: review and endorsement
of the Master of Science degree program in Real Estate Development which completed the
third year of its 5-year initial approval; approval of a Doctoral Program in Speech and
Hearing Sciences to be offered by the Health Sciences and Technology Program (HST); and
deferral of a Master of Science degree program proposed by the MIT/Woods Hole
Oceanographic Institution (WHOI) Joint Program. Last year's CGSP proposal to change the
wording of doctoral diplomas was presented to the Faculty Policy Committee (FPC) for its
endorsement; the FPC offered a counter proposal which was rejected by the CGSP; the CGSP
then voted unanimously to return the original proposal to the FPC. Action on this
matter will be taken early next year. In addition to these and various other matters,
the CGSP carried out its usual academic review functions at the end of each term by
reviewing grades, issuing academic warnings where appropriate, terminating the
registration for several students whose performance was unsatisfactory, and recommending
candidates for advanced degrees.

The operation of the ODGS suffered a severe blow due to the illness of Associate Dean
Jeanne E. Richard who was forced to be absent for almost the entire year. The remaining
staff of the office performed admirably in Dean Richard's absence and saw to it that the
many services provided to graduate students and their academic departments were carried
out in an effective manner. Special thanks are due Jean Frank, Chris Palmer, Linda
Peterson, and Jackie Sciacca who carried out their tasks faithfully throughout a
difficult year. Our efforts at increasing the level of computer use in the office were
severely hampered, but almost all other tasks and initiatives were completed as planned.

Despite Dean Richard's absence we continued to pay special attention to the recruitment
of women graduate students and to the environment in which they study and work. Data
relating to the admission, enrollment, and degrees awarded to women are presented in
Tables VII - XII. These data indicate that we appear to have reached a relatively
stagnant situation with women's enrollment levelled off at 20 percent of the total
graduate student enrollment, applications from women essentially unchanged while
applications from men increased by 10 percent in the past year, and the percentage of
graduate degrees awarded to women up only slightly to 21 percent of the total. It
appears that many important data pertaining to women are tending to stagnate at about
the 20 percent level after a decade or more of steady growth from much lower values.
This pattern is similar to that which occurred a few years ago at the undergraduate
level. Major efforts were required at that time to advance beyond the 20 percent
barrier, and have in recent years produced freshmen classes with women's enrollment of
well above 30 percent. We can hope that these recent increases at the undergraduate
level presage large increases at the graduate level in the next few years; however, a
realistic assessment suggests that such increases will not happen automatically.
Rather, new efforts at all levels will be required to ensure that the successes of the
past decade are not followed by an extended period of stagnation or even decline.

Last year's report called attention to a new initiative taken by Associate Dean John B.
Turner to attract minority graduate students to the School of Science. The summer
Science Program for Minorities had a most successful beginning with 8 students in the
summer of 1986 and will expand to 12 students in 1987. This small but innovative
program is the most recent example of numerous efforts which Dean Turner has initiated
to attract minority graduate students to MIT and to make their stay here as productive
as possible.

I and my colleagues in the ODGS wish to express our thanks and appreciation to members
of the CGSP for their service during the past year. Those terminating their service
this year and their replacements are:

Materials Science and Engineering
Professor Samuel Allen to Professor John Vandersande

Biology
Professor David Botstein to Professor Robert Sauer

Brain and Cognitive Sciences
Professor Merrill Garrett to Professor William G. Quinn, Jr.

Chemical Engineering
Professor William Deen to Professor Robert Armstrong

Earth, Atmospheric & Planetary Sciences
Professor Peter Stone to Professor Charles Counselman, III

Linguistics & Philosophy
Professor Sylvain Bromberger to Professor Paul Horwich

FRANK E. PERKINS

MINORITY GRADUATE STUDENT AFFAIRS 1986-87

Minority graduate student affairs at MIT for 1986-87 experienced a very good year as evidenced by the five-percent increase in minority graduate student enrollment over 1985-86 and by the large number of minority students (54) earning graduate degrees (see Table XVI). The success at MIT can be attributed to a number of efforts that have been put in place over the past 13 years by the Office of the Dean of the Graduate School in assisting graduate departments to recruit, retain, and graduate underrepresented minority graduate students. These efforts include a small increase in the recruiting budget from the Provost's Office, several early identification and summer feeder programs, success of our current minority graduate students, our network in feeder schools, and the good will we have established around the country in taking a leadership position in minority graduate education.

JOHN B. TURNER
For simple comparison with data for 1985-86, the following statistical information for 1986-87 is presented in the same format. Numbers in parentheses indicate the change from 1985-86 to 1986-87.

### REGULAR GRADUATE STUDENT ENROLLMENT - FALL TERM 1986

<table>
<thead>
<tr>
<th>School of Architecture and Planning</th>
<th>Foreign</th>
<th>Women(^{(1)})</th>
<th>Minority(^{(2)})</th>
<th>Total</th>
<th>Non-Resident(^{(3)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>156(-15)</td>
<td>158(-1)</td>
<td>23(+3)</td>
<td>458(+17)</td>
<td>41(NC)</td>
<td></td>
</tr>
<tr>
<td>School of Engineering</td>
<td>774(-106)</td>
<td>320(+12)</td>
<td>62(NC)</td>
<td>2403(+36)</td>
<td>28(+20)</td>
</tr>
<tr>
<td>School of Humanities and Social Science(^{(4)})</td>
<td>107(-10)</td>
<td>107(-11)</td>
<td>10(-8)</td>
<td>358(-51)</td>
<td>79(+15)</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>167(+2)</td>
<td>116(+6)</td>
<td>20(+3)</td>
<td>588(+27)</td>
<td>11(+2)</td>
</tr>
<tr>
<td>School of Science</td>
<td>284(-35)</td>
<td>267(-7)</td>
<td>27(+5)</td>
<td>1097(-4)</td>
<td>16(-2)</td>
</tr>
<tr>
<td>Whitaker College(^{(4)})</td>
<td>6</td>
<td>15</td>
<td>2</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>Health Science &amp; Technology</td>
<td>3(-3)</td>
<td>4(-6)</td>
<td>0(NC)</td>
<td>23(-9)</td>
<td>0(NC)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1497(-161)</strong></td>
<td><strong>987(+6)</strong></td>
<td><strong>144(+5)</strong></td>
<td><strong>4979(+59)</strong></td>
<td><strong>175(+35)</strong></td>
</tr>
</tbody>
</table>

\(^{(1)}\)See also Table IX.

\(^{(2)}\)Includes Black Americans, Puerto Ricans, Mexican Americans, and American Indians.

\(^{(3)}\)Included in Totals.

\(^{(4)}\)Whitaker College contains the Department of Brain and Cognitive Sciences which was previously included in the data for the School of Humanities and Social Sciences.
### TABLE II

GRADUATE DEGREES AWARDED: 1986-87

<table>
<thead>
<tr>
<th>Advanced Degrees Conferred</th>
<th>M.C.P.</th>
<th>M. Arch</th>
<th>S.M.</th>
<th>Engineer</th>
<th>Sc.D.</th>
<th>Ph.D.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1986</td>
<td>6(+3)</td>
<td>184(-2)</td>
<td>3(-4)</td>
<td>9(+3)</td>
<td>98(+2)</td>
<td>303(+3)</td>
<td></td>
</tr>
<tr>
<td>Woods Hole</td>
<td>0(NC)</td>
<td>0(-1)</td>
<td>3(+2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1987</td>
<td>16(+1)</td>
<td>226(+37)</td>
<td>13(-3)</td>
<td>16(+2)</td>
<td>144(+12)</td>
<td>421(+48)</td>
<td></td>
</tr>
<tr>
<td>Woods Hole</td>
<td>0(NC)</td>
<td>1(NC)</td>
<td>5(-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 1987</td>
<td>59(-2)</td>
<td>659(+54)</td>
<td>26(-5)</td>
<td>17(-11)</td>
<td>165(+1)</td>
<td>927(+32)</td>
<td></td>
</tr>
<tr>
<td>Woods Hole</td>
<td>0(NC)</td>
<td>0(-3)</td>
<td>1(-2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>81(+2)</td>
<td>1069(+89)</td>
<td>42(-12)</td>
<td>43(-10)</td>
<td>416(+14)</td>
<td>1651(+83)</td>
<td></td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate change from 1985-86 to 1986-87.
### TABLE III

**DOCTORAL DEGREES AWARDED EACH YEAR BY SCHOOL AND CITIZENSHIP**

Each number is the total of the doctoral degrees awarded in September, February and June of the academic year indicated. The numbers in parentheses are the number of degrees awarded divided by the corresponding regular graduate student enrollment (5th week count).

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Arch.</th>
<th>Eng’g.</th>
<th>Hum. and Soc. Sci.</th>
<th>Sloan</th>
<th>Science</th>
<th>HST</th>
<th>Whitaker College</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977-78 Citizen</td>
<td>5(.023)</td>
<td>111(.096)</td>
<td>50(.240)</td>
<td>8(.029)</td>
<td>119(.146)</td>
<td>293(.110)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>3(.039)</td>
<td>66(.103)</td>
<td>13(.169)</td>
<td>15(.139)</td>
<td>35(.141)</td>
<td>132(.115)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978-79 Citizen</td>
<td>10(.0431)</td>
<td>80(.066)</td>
<td>35(.164)</td>
<td>10(.035)</td>
<td>126(.151)</td>
<td>261(.093)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>3(.033)</td>
<td>64(.101)</td>
<td>11(.130)</td>
<td>9(.088)</td>
<td>33(.142)</td>
<td>120(.105)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1979-80 Citizen</td>
<td>8(.031)</td>
<td>96(.074)</td>
<td>40(.156)</td>
<td>5(.017)</td>
<td>127(.153)</td>
<td>276(.094)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>3(.034)</td>
<td>66(.096)</td>
<td>11(.109)</td>
<td>3(.029)</td>
<td>28(.115)</td>
<td>111(.091)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980-81 Citizen</td>
<td>12(.044)</td>
<td>88(.065)</td>
<td>40(.178)</td>
<td>7(.022)</td>
<td>118(.138)</td>
<td>265(.088)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>7(.078)</td>
<td>75(.103)</td>
<td>12(.153)</td>
<td>2(.020)</td>
<td>35(.130)</td>
<td>131(.104)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981-82 Citizen</td>
<td>7(.023)</td>
<td>94(.066)</td>
<td>35(.128)</td>
<td>4(.012)</td>
<td>124(.148)</td>
<td>264(.083)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>2(.017)</td>
<td>75(.104)</td>
<td>21(.223)</td>
<td>6(.050)</td>
<td>35(.123)</td>
<td>139(.103)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982-83 Citizen</td>
<td>6(.026)</td>
<td>93(.070)</td>
<td>43(.189)</td>
<td>11(.031)</td>
<td>126(.160)</td>
<td>1(.100)</td>
<td>280(.096)</td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>4(.027)</td>
<td>78(.102)</td>
<td>14(.150)</td>
<td>2(.016)</td>
<td>52(.184)</td>
<td>2(.222)</td>
<td>152(.107)</td>
<td></td>
</tr>
<tr>
<td>1983-84 Citizen</td>
<td>9(.035)</td>
<td>92(.065)</td>
<td>41(.182)</td>
<td>12(.035)</td>
<td>115(.150)</td>
<td>3(.130)</td>
<td>272(.089)</td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>5(.040)</td>
<td>76(.098)</td>
<td>16(.168)</td>
<td>9(.059)</td>
<td>37(.128)</td>
<td>0</td>
<td>143(.099)</td>
<td></td>
</tr>
<tr>
<td>1984-85 Citizen</td>
<td>10(.031)</td>
<td>111(.074)</td>
<td>32(.104)</td>
<td>7(.019)</td>
<td>128(.161)</td>
<td>3(.142)</td>
<td>291(.088)</td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>3(.026)</td>
<td>76(.098)</td>
<td>15(.167)</td>
<td>11(.065)</td>
<td>50(.167)</td>
<td>1(.500)</td>
<td>156(.108)</td>
<td></td>
</tr>
<tr>
<td>1985-86 Citizen</td>
<td>7(.026)</td>
<td>119(.080)</td>
<td>46(.157)</td>
<td>4(.010)</td>
<td>122(.156)</td>
<td>3(.115)</td>
<td>301(.092)</td>
<td></td>
</tr>
<tr>
<td>Foreign</td>
<td>3(.017)</td>
<td>89(.101)</td>
<td>12(.102)</td>
<td>5(.030)</td>
<td>46(.144)</td>
<td>1(.166)</td>
<td>156(.094)</td>
<td></td>
</tr>
<tr>
<td>1986-87 Citizen</td>
<td>12(.039)</td>
<td>137(.084)</td>
<td>39(.016)</td>
<td>6(.014)</td>
<td>116(.014)</td>
<td>5(.250)</td>
<td>5(.096)</td>
<td>319(.091)</td>
</tr>
<tr>
<td>Foreign</td>
<td>2(.012)</td>
<td>80(.010)</td>
<td>10(.093)</td>
<td>10(.060)</td>
<td>42(.015)</td>
<td>0(.00)</td>
<td>0(.00)</td>
<td>140(.093)</td>
</tr>
</tbody>
</table>
TABLE IV
A "SNAPSHOT" OF GRADUATE STUDENT SUPPORT "FULL AWARDS"
FALL TERM 1986

The following sources provided at least full tuition support for graduate students during the Fall Term 1986. Total regular graduate student enrollment, not including Non-Residents, was 4,804.

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>% of Total Enrollment</th>
<th>Change from 1985-86</th>
</tr>
</thead>
<tbody>
<tr>
<td>FELLOWSHIPS &amp; TRAINEESHIPS AWARDED BY MIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIH and NIMH Traineeships</td>
<td>64</td>
<td>-14</td>
</tr>
<tr>
<td>HEW Graduate and Professional Opportunities</td>
<td>16</td>
<td>+ 3</td>
</tr>
<tr>
<td>Program Fellowships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIT Endowed and Other Fund Fellowships</td>
<td>200</td>
<td>+10</td>
</tr>
<tr>
<td>Industrial and Foundation Fellowships</td>
<td>164</td>
<td>-24</td>
</tr>
<tr>
<td></td>
<td>444</td>
<td>9.2%</td>
</tr>
<tr>
<td>FELLOWSHIPS AWARDED BY SPONSORS TO MIT STUDENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSF Graduate Fellowships</td>
<td>187</td>
<td>+ 4</td>
</tr>
<tr>
<td>Hertz Fellowships</td>
<td>30</td>
<td>- 1</td>
</tr>
<tr>
<td>ONR Fellowships</td>
<td>27</td>
<td>+ 6</td>
</tr>
<tr>
<td></td>
<td>244</td>
<td>5.0%</td>
</tr>
<tr>
<td>STUDENT ASSISTANTSHIPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Assistants</td>
<td>1608</td>
<td>+73</td>
</tr>
<tr>
<td>Teaching Assistants</td>
<td>411</td>
<td>+ 7</td>
</tr>
<tr>
<td>Instructor G</td>
<td>7</td>
<td>+ 2</td>
</tr>
<tr>
<td></td>
<td>2026</td>
<td>42.2%</td>
</tr>
<tr>
<td>SPONSORED STUDENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many students receive support from employers and sponsors. The following reflect accounts billing for tuition to employers and sponsors who presumably provide stipends to students by private arrangement:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. Government</td>
<td>129</td>
<td>+ 2</td>
</tr>
<tr>
<td>Foreign Countries and International Programs</td>
<td>140</td>
<td>-17</td>
</tr>
<tr>
<td>Industry and Foundation (U.S.)</td>
<td>103</td>
<td>-40</td>
</tr>
<tr>
<td></td>
<td>372</td>
<td>7.7%</td>
</tr>
<tr>
<td>SUMMARY BY SOURCES - FULL AWARDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal Fellowships &amp; Traineeships</td>
<td>294</td>
<td>6.1%</td>
</tr>
<tr>
<td>Graduate Student Staff</td>
<td>2026</td>
<td>42.2%</td>
</tr>
<tr>
<td>Industrial and Foundation Awards</td>
<td>194</td>
<td>4.0%</td>
</tr>
<tr>
<td>MIT Endowed and Budgeted Funds</td>
<td>200</td>
<td>4.2%</td>
</tr>
<tr>
<td>Students Sponsored by External Sources</td>
<td>372</td>
<td>7.7%</td>
</tr>
<tr>
<td></td>
<td>3086</td>
<td>64.2%</td>
</tr>
</tbody>
</table>
TABLE V

DISTRIBUTION OF FUNDING FOR GRADUATE STUDENT TUITION AND LIVING EXPENSES
FALL TERM 1986

<table>
<thead>
<tr>
<th>Estimates of Required Funding</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition</td>
<td>29,948,685</td>
<td></td>
</tr>
<tr>
<td>Stipend</td>
<td>21,285,225</td>
<td></td>
</tr>
<tr>
<td>Total Estimated Required Funding</td>
<td>51,233,910</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identified Support by Category</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Assistantships</td>
<td>22,191,469</td>
<td>(43.3%)</td>
</tr>
<tr>
<td>Teaching Assistantships</td>
<td>9,483,528</td>
<td>(18.5%)</td>
</tr>
<tr>
<td>Federal Fellowships and Traineeships</td>
<td>4,273,957</td>
<td>( 8.4%)</td>
</tr>
<tr>
<td>General and Endowed Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(departmentally controlled)</td>
<td>2,111,253</td>
<td>( 4.2%)</td>
</tr>
<tr>
<td>General and Endowed Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Graduate School Office controlled)</td>
<td>581,121</td>
<td>( 1.1%)</td>
</tr>
<tr>
<td>Outside Sources Administered by Departments</td>
<td>1,833,050</td>
<td>( 3.6%)</td>
</tr>
<tr>
<td>Outside Sources Administered by Graduate School Office</td>
<td>359,581</td>
<td>(.7%)</td>
</tr>
<tr>
<td>Outside Sources, Direct Billing to Sponsor by Institute, Tuition only</td>
<td>2,194,800</td>
<td>( 4.3%)</td>
</tr>
<tr>
<td>Total Identified Support</td>
<td>43,028,759</td>
<td>(84%)</td>
</tr>
</tbody>
</table>

| Loans                             | 5,858,000  | (11.4%)|


TABLE VI

TRENDS IN GRADUATE STUDENT SUPPORT
($000's)

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Fellowships</th>
<th>Traineeships</th>
<th>Staff Tuition**</th>
<th>Staff Salaries (TA &amp; IG)</th>
<th>MIT Only</th>
<th>Including Outside Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>5,396 (.655)</td>
<td>1,182 (.143)</td>
<td>6,850 (.831)</td>
<td>483 (.059)</td>
<td>672 (.082)</td>
<td></td>
</tr>
<tr>
<td>1971-72</td>
<td>5,076 (.589)</td>
<td>1,294 (.150)</td>
<td>7,086 (.823)</td>
<td>696 (.080)</td>
<td>827 (.096)</td>
<td></td>
</tr>
<tr>
<td>1972-73</td>
<td>4,687 (.486)</td>
<td>1,432 (.150)</td>
<td>7,991 (.828)</td>
<td>754 (.078)</td>
<td>916 (.095)</td>
<td></td>
</tr>
<tr>
<td>1973-74</td>
<td>3,930 (.378)</td>
<td>1,453 (.140)</td>
<td>8,781 (.844)</td>
<td>852 (.082)</td>
<td>1,014 (.097)</td>
<td></td>
</tr>
<tr>
<td>1974-75</td>
<td>3,693 (.318)</td>
<td>1,738 (.150)</td>
<td>9,760 (.840)</td>
<td>1,075 (.093)</td>
<td>1,293 (.111)</td>
<td></td>
</tr>
<tr>
<td>1975-76</td>
<td>3,447 (.259)</td>
<td>1,878 (.141)</td>
<td>10,878 (.816)</td>
<td>1,141 (.086)</td>
<td>1,407 (.106)</td>
<td></td>
</tr>
<tr>
<td>1976-77</td>
<td>3,454 (.229)</td>
<td>2,065 (.137)</td>
<td>11,654 (.722)</td>
<td>1,419 (.094)</td>
<td>2,013 (.133)</td>
<td></td>
</tr>
<tr>
<td>1977-78</td>
<td>3,418 (.205)</td>
<td>1,978 (.118)</td>
<td>12,479 (.750)</td>
<td>1,391 (.084)</td>
<td>2,201 (.132)</td>
<td></td>
</tr>
<tr>
<td>1978-79</td>
<td>3,667 (.189)</td>
<td>2,355 (.127)</td>
<td>15,251 (.823)</td>
<td>962 (.052)</td>
<td>2,387 (.129)</td>
<td></td>
</tr>
<tr>
<td>1979-80</td>
<td>3,773 (.172)</td>
<td>3,079 (.142)</td>
<td>16,610 (.766)</td>
<td>976 (.045)</td>
<td>3,575 (.165)</td>
<td></td>
</tr>
<tr>
<td>1980-81</td>
<td>3,970 (.149)</td>
<td>2,821 (.106)</td>
<td>18,650 (.702)</td>
<td>434 (.016)</td>
<td>4,434 (.167)</td>
<td></td>
</tr>
<tr>
<td>1981-82</td>
<td>4,194 (.128)</td>
<td>3,362 (.102)</td>
<td>21,258 (.648)</td>
<td>662 (.020)</td>
<td>5,412 (.165)</td>
<td></td>
</tr>
<tr>
<td>1982-83</td>
<td>5,142 (.136)</td>
<td>4,044 (.107)</td>
<td>21,993 (.581)</td>
<td>1,078 (.028)</td>
<td>4,791 (.126)</td>
<td></td>
</tr>
<tr>
<td>1983-84</td>
<td>5,561 (.130)</td>
<td>19,094 (.445)</td>
<td>12,671 (.295)</td>
<td>1,602 (.037)</td>
<td>4,576 (.106)</td>
<td></td>
</tr>
<tr>
<td>1984-85</td>
<td>6,516 (.137)</td>
<td>21,541 (.454)</td>
<td>14,131 (.298)</td>
<td>1,821 (.038)</td>
<td>5,135 (.108)</td>
<td></td>
</tr>
<tr>
<td>1985-86</td>
<td>7,249 (.138)</td>
<td>25,325 (.482)</td>
<td>16,237 (.309)</td>
<td>1,600 (.034)</td>
<td>4,947 (.094)</td>
<td></td>
</tr>
<tr>
<td>1986-87</td>
<td>8,045 (.142)</td>
<td>27,751 (.490)</td>
<td>17,841 (.315)</td>
<td>1,254 (.022)</td>
<td>4,604 (.081)</td>
<td></td>
</tr>
</tbody>
</table>

*Administered by the Office of the Dean of the Graduate School.

**Beginning with the academic year 1983-84, tuition awarded to Research Assistants is included under "Staff Tuition Awards."

To "normalize" these data, the total dollar values have been divided by the product (total regular graduate students registered for the fall term) (tuition for the 9-month academic year).
TABLE VII

WOMEN GRADUATE STUDENT ENROLLMENT
Comparison of Fall Term Enrollments - 1985 & 1986

<table>
<thead>
<tr>
<th>School of Architecture &amp; Planning</th>
<th>Number of Women 1985</th>
<th>Number of Women 1986</th>
<th>Total Enrollment 1985</th>
<th>Total Enrollment 1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>79</td>
<td>79</td>
<td>32%</td>
<td>28%</td>
</tr>
<tr>
<td>Urban Studies &amp; Planning</td>
<td>80</td>
<td>79</td>
<td>42%</td>
<td>44%</td>
</tr>
<tr>
<td></td>
<td>159</td>
<td>158</td>
<td>36%</td>
<td>34%</td>
</tr>
<tr>
<td>School of Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics &amp; Astronautics</td>
<td>20</td>
<td>19</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>34</td>
<td>33</td>
<td>15%</td>
<td>14%</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>30</td>
<td>39</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>Elec. Engineering &amp; Comp. Science</td>
<td>107</td>
<td>101</td>
<td>16%</td>
<td>15%</td>
</tr>
<tr>
<td>Materials Science</td>
<td>52</td>
<td>58</td>
<td>19%</td>
<td>22%</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>39</td>
<td>41</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Nuclear Engineering</td>
<td>17</td>
<td>18</td>
<td>11%</td>
<td>12%</td>
</tr>
<tr>
<td>Ocean Engineering</td>
<td>9</td>
<td>11</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>320</td>
<td>13%</td>
<td>13%</td>
</tr>
<tr>
<td>School of Humanities &amp; Social Sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>16</td>
<td>22</td>
<td>12%</td>
<td>17%</td>
</tr>
<tr>
<td>Linguistics &amp; Philosophy</td>
<td>31</td>
<td>30</td>
<td>48%</td>
<td>46%</td>
</tr>
<tr>
<td>Political Science</td>
<td>58</td>
<td>55</td>
<td>33%</td>
<td>34%</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>107</td>
<td>29%</td>
<td>30%</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>110</td>
<td>116</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>School of Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Biological Sciences</td>
<td>49</td>
<td>45</td>
<td>43%</td>
<td>45%</td>
</tr>
<tr>
<td>Biology</td>
<td>56</td>
<td>66</td>
<td>35%</td>
<td>39%</td>
</tr>
<tr>
<td>Chemistry</td>
<td>61</td>
<td>60</td>
<td>27%</td>
<td>27%</td>
</tr>
<tr>
<td>Earth, Atmospheric &amp; Planetary Science</td>
<td>53</td>
<td>54</td>
<td>28%</td>
<td>28%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>17</td>
<td>12</td>
<td>14%</td>
<td>10%</td>
</tr>
<tr>
<td>Physics</td>
<td>38</td>
<td>30</td>
<td>13%</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>274</td>
<td>267</td>
<td>25%</td>
<td>24%</td>
</tr>
<tr>
<td>Whitaker College*</td>
<td>15</td>
<td>15</td>
<td>32%</td>
<td>29%</td>
</tr>
<tr>
<td>HST</td>
<td>10</td>
<td>4</td>
<td>31%</td>
<td>17%</td>
</tr>
<tr>
<td>TOTALS</td>
<td>981</td>
<td>987</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

*Formerly reported as Psychology and HPM.
<table>
<thead>
<tr>
<th>Fall Term</th>
<th>Women</th>
<th>Total</th>
<th>% of Women</th>
<th>Women</th>
<th>Total</th>
<th>% of Women</th>
<th>Women</th>
<th>Total</th>
<th>% of Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>140</td>
<td>1,061</td>
<td>13%</td>
<td>265</td>
<td>2,407</td>
<td>11%</td>
<td>405</td>
<td>3,468</td>
<td>12%</td>
</tr>
<tr>
<td>1975</td>
<td>175</td>
<td>1,113</td>
<td>16%</td>
<td>312</td>
<td>2,490</td>
<td>12.5%</td>
<td>487</td>
<td>3,603</td>
<td>13.5%</td>
</tr>
<tr>
<td>1976</td>
<td>185</td>
<td>1,220</td>
<td>15%</td>
<td>361</td>
<td>2,554</td>
<td>14%</td>
<td>546</td>
<td>3,774</td>
<td>14%</td>
</tr>
<tr>
<td>1977</td>
<td>192</td>
<td>1,184</td>
<td>16%</td>
<td>367</td>
<td>2,640</td>
<td>14%</td>
<td>559</td>
<td>3,824</td>
<td>14.6%</td>
</tr>
<tr>
<td>1978</td>
<td>218</td>
<td>1,259</td>
<td>17%</td>
<td>388</td>
<td>2,685</td>
<td>14%</td>
<td>606</td>
<td>3,944</td>
<td>15.4%</td>
</tr>
<tr>
<td>1979</td>
<td>193</td>
<td>1,202</td>
<td>16%</td>
<td>491</td>
<td>2,944</td>
<td>16.6%</td>
<td>684</td>
<td>4,146</td>
<td>16.4%</td>
</tr>
<tr>
<td>1980</td>
<td>254</td>
<td>1,308</td>
<td>19%</td>
<td>525</td>
<td>3,076</td>
<td>17%</td>
<td>779</td>
<td>4,384</td>
<td>18%</td>
</tr>
<tr>
<td>1981</td>
<td>243</td>
<td>1,272</td>
<td>19%</td>
<td>585</td>
<td>3,269</td>
<td>18%</td>
<td>828</td>
<td>4,541</td>
<td>18%</td>
</tr>
<tr>
<td>1982</td>
<td>267</td>
<td>1,306</td>
<td>20%</td>
<td>589</td>
<td>3,183</td>
<td>19%</td>
<td>856</td>
<td>4,489</td>
<td>19%</td>
</tr>
<tr>
<td>1983</td>
<td>258</td>
<td>1,302</td>
<td>20%</td>
<td>656</td>
<td>3,329</td>
<td>20%</td>
<td>914</td>
<td>4,631</td>
<td>20%</td>
</tr>
<tr>
<td>1984</td>
<td>265</td>
<td>1,290</td>
<td>20.5%</td>
<td>716</td>
<td>3,467</td>
<td>21%</td>
<td>981</td>
<td>4,757</td>
<td>21%</td>
</tr>
<tr>
<td>1985</td>
<td>255</td>
<td>1,375</td>
<td>18.5%</td>
<td>726</td>
<td>3,546</td>
<td>20%</td>
<td>981</td>
<td>4,920</td>
<td>20%</td>
</tr>
<tr>
<td>1986</td>
<td>238</td>
<td>1,288</td>
<td>18.5%</td>
<td>749</td>
<td>3,691</td>
<td>20%</td>
<td>987</td>
<td>4,979</td>
<td>20%</td>
</tr>
</tbody>
</table>
**TABLE IX**

**COMPARISON OF FALL ADMISSIONS STATISTICS FOR GRADUATE WOMEN AND GRADUATE MEN**

<table>
<thead>
<tr>
<th>School of Architecture</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>243/250(+3%)*</td>
<td>482/566(+17%)*</td>
</tr>
<tr>
<td>School of Engineering</td>
<td>369/415(+12%)</td>
<td>3038/3504(+15%)</td>
</tr>
<tr>
<td>School of Humanities &amp; Social Science***</td>
<td>250/162(-35%)</td>
<td>504/483(-4%)</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>350/342(-2%)</td>
<td>1446/1416(-2%)</td>
</tr>
<tr>
<td>School of Science</td>
<td>391/390(NC)</td>
<td>1216/1324(+9%)</td>
</tr>
<tr>
<td>Whitaker College**</td>
<td>/46</td>
<td>/58</td>
</tr>
<tr>
<td>HST**</td>
<td>/1</td>
<td>/9</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>1603/1606(NC)</td>
<td>6686/7360(+10%)</td>
</tr>
</tbody>
</table>

* Numbers in parentheses indicate the % change in number of applicants from 1985 to 1986.
** Figures not available for 1985.
*** Through 1985 the Department of Brain and Cognitive Sciences (formerly Psychology) was included in the School of Humanities & Social Science; it is now included in the Whitaker College.
**TABLE X**

**COMPARISON OF WOMEN ENROLLED WITH WOMEN DEGREE RECIPIENTS, 1986-87**

<table>
<thead>
<tr>
<th></th>
<th>% of Women Enrolled</th>
<th>% of Degrees awarded to Women Masters</th>
<th>Doctoral</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Architecture and Planning</strong></td>
<td>34% (36%)</td>
<td>38% (40%)</td>
<td>43% (6/14)</td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
<td>13% (13%)</td>
<td>16% (16%)</td>
<td>11% (24/216)</td>
</tr>
<tr>
<td><strong>Humanities &amp; Social Science</strong></td>
<td>30% (29%)</td>
<td>39% (42%)</td>
<td>24% (12/49)</td>
</tr>
<tr>
<td><strong>Sloan School of Management</strong></td>
<td>20% (20%)</td>
<td>24% (19%)</td>
<td>25% (4/16)</td>
</tr>
<tr>
<td><strong>Science</strong></td>
<td>24% (25%)</td>
<td>24% (24%)</td>
<td>23% (34/147)</td>
</tr>
<tr>
<td><strong>Whitaker College</strong></td>
<td>29% (15/52)</td>
<td>none</td>
<td>50% (1/2)</td>
</tr>
<tr>
<td><strong>HST</strong></td>
<td>17% (31%)</td>
<td>none</td>
<td>20% (1/5)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>20% (20%)</td>
<td>22% (244/1109)</td>
<td>18% (82/449)</td>
</tr>
<tr>
<td><strong>ALL DEGREES</strong></td>
<td></td>
<td>21% (326/1558)</td>
<td>(20%)</td>
</tr>
</tbody>
</table>

(% = 1985-86 figures)
TABLE XI

Degrees Awarded to Women by School

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture &amp; Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's*</td>
<td>23</td>
<td>33</td>
<td>41</td>
<td>48</td>
<td>51</td>
<td>48</td>
<td>50</td>
<td>48</td>
<td>62</td>
<td>64</td>
</tr>
<tr>
<td>Doctor's</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>42</td>
<td>50</td>
<td>51</td>
<td>52</td>
<td>84</td>
<td>72</td>
<td>81</td>
<td>77</td>
<td>95</td>
<td>92</td>
</tr>
<tr>
<td>Doctor's</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>14</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Humanities &amp; Social Sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Doctor's</td>
<td>12</td>
<td>4</td>
<td>12</td>
<td>14</td>
<td>10</td>
<td>14</td>
<td>20</td>
<td>14</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Sloan (XV, XV-A, XV-P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>40</td>
<td>45</td>
<td>34</td>
<td>49</td>
<td>47</td>
<td>47</td>
<td>54</td>
<td>57</td>
<td>48</td>
<td>69</td>
</tr>
<tr>
<td>Doctor's</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>25</td>
<td>14</td>
<td>27</td>
<td>21</td>
<td>25</td>
<td>25</td>
<td>23</td>
<td>6</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Doctor's</td>
<td>23</td>
<td>18</td>
<td>20</td>
<td>26</td>
<td>23</td>
<td>29</td>
<td>25</td>
<td>37</td>
<td>47</td>
<td>34</td>
</tr>
<tr>
<td>Operations Research (XV-B)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Doctor's</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WHOI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor's</td>
<td>1(VII-W)</td>
<td>1(VII-W)</td>
<td>0</td>
<td>1(VII-W)</td>
<td>2(XII-W)</td>
<td>3(XII-W)</td>
<td>2(XII-W)</td>
<td>1(VII-W)</td>
<td>2(XII-W)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>1(XII-W)</td>
<td>2(XII-W)</td>
<td>1(VII-W)</td>
</tr>
<tr>
<td>HST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor's</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Whitaker College</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor's</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>135</td>
<td>145</td>
<td>156</td>
<td>184</td>
<td>214</td>
<td>198</td>
<td>211</td>
<td>196</td>
<td>220</td>
<td>244</td>
</tr>
<tr>
<td>Doctor's</td>
<td>48</td>
<td>29</td>
<td>47</td>
<td>65</td>
<td>49</td>
<td>71</td>
<td>61</td>
<td>78</td>
<td>87</td>
<td>85</td>
</tr>
</tbody>
</table>

*M.Arch., MCP, SM
<table>
<thead>
<tr>
<th></th>
<th>Master's % of Women</th>
<th>Doctor's % of Women</th>
<th>Engineer's % of Women</th>
<th>All % of Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women</td>
<td>Total</td>
<td>Women</td>
<td>Total</td>
</tr>
<tr>
<td>1976-77</td>
<td>145</td>
<td>971</td>
<td>15%</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1977-78</td>
<td>135</td>
<td>934</td>
<td>14%</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978-79</td>
<td>145</td>
<td>968</td>
<td>15%</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1979-80</td>
<td>156</td>
<td>984</td>
<td>16%</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980-81</td>
<td>184</td>
<td>1018</td>
<td>18%</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981-82</td>
<td>214</td>
<td>1118</td>
<td>19%</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982-83</td>
<td>198</td>
<td>1124</td>
<td>17.5%</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983-84</td>
<td>211</td>
<td>1084</td>
<td>19%</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984-85</td>
<td>196</td>
<td>1055</td>
<td>18.5%</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985-86</td>
<td>220</td>
<td>1059</td>
<td>21%</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986-87</td>
<td>244</td>
<td>1150</td>
<td>21%</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Without Engineer's Degrees
## TABLE XIII
### MINORITY GRADUATE STUDENT ENROLLMENT
#### Fall of 1986

<table>
<thead>
<tr>
<th>School of Architecture &amp; Planning</th>
<th>Total Minority</th>
<th>% change from 1985</th>
<th>Total Regular Grads</th>
<th>% Minority</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>PR</td>
<td>MA</td>
<td>AI</td>
<td>BA</td>
</tr>
<tr>
<td>Architecture</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Urban Studies &amp; Planning</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>School Totals</td>
<td>15</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>School of Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics &amp; Astronautics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Electrical Eng'g. &amp; Comp. Sci.</td>
<td>21</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Materials Science</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nuclear Engineering</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ocean Engineering</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>School Totals</td>
<td>37</td>
<td>10</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-Year's Master's Program</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Sloan Fellows</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Operations Research</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ph.D. Program</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>School Totals</td>
<td>13</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Humanities &amp; Soc. Sci. School</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Linguistics &amp; Philosophy</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Political Science</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>School Totals</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>School of Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Biological Sciences</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biology</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chemistry</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Earth, Atmospheric, &amp; Planetary</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Physics</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>School Totals</td>
<td>20</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Whitaker College</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Health Science &amp; Technology</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>95</td>
<td>22</td>
<td>25</td>
<td>4</td>
</tr>
</tbody>
</table>
### Table XIV

**Trends in Minority Graduate Enrollment at MIT**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture &amp; Planning</td>
<td>59</td>
<td>44</td>
<td>46</td>
<td>45</td>
<td>57</td>
<td>41</td>
<td>31</td>
<td>35</td>
<td>26</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Engineering</td>
<td>44</td>
<td>40</td>
<td>44</td>
<td>47</td>
<td>58</td>
<td>55</td>
<td>55</td>
<td>62</td>
<td>58</td>
<td>62</td>
<td>58</td>
</tr>
<tr>
<td>Management</td>
<td>17</td>
<td>20</td>
<td>13</td>
<td>9</td>
<td>16</td>
<td>10</td>
<td>12</td>
<td>7</td>
<td>18</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Humanities and Social Sciences</td>
<td>27</td>
<td>21</td>
<td>16</td>
<td>9</td>
<td>15</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td>13</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Science</td>
<td>31</td>
<td>32</td>
<td>28</td>
<td>34</td>
<td>25</td>
<td>25</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>HST</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Whitaker College</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Minority Total</td>
<td>178</td>
<td>157</td>
<td>147</td>
<td>144</td>
<td>171</td>
<td>140</td>
<td>138</td>
<td>145</td>
<td>141</td>
<td>139</td>
<td>146</td>
</tr>
<tr>
<td>Regular Graduate Total</td>
<td>3744</td>
<td>3824</td>
<td>3944</td>
<td>4146</td>
<td>4327</td>
<td>4435</td>
<td>4349</td>
<td>4631</td>
<td>4603</td>
<td>4920</td>
<td>4424</td>
</tr>
</tbody>
</table>

### Black Graduate Enrollment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture &amp; Planning</td>
<td>30</td>
<td>23</td>
<td>25</td>
<td>19</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Engineering</td>
<td>35</td>
<td>34</td>
<td>41</td>
<td>41</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Management</td>
<td>10</td>
<td>12</td>
<td>5</td>
<td>14</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Humanities &amp; Social Sciences</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Science</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>HPM</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>HST</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Total Black Enrollment</td>
<td>97</td>
<td>93</td>
<td>99</td>
<td>99</td>
<td>89</td>
<td>95</td>
</tr>
</tbody>
</table>
TABLE XV
MINORITY APPLICANTS RECEIVED, ADMITTED, AND ENROLLED
1985-86 vs 1986-87

<table>
<thead>
<tr>
<th>Architecture &amp; Planning</th>
<th>1985-86</th>
<th>1986-87</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rec'd</td>
<td>Ad</td>
</tr>
<tr>
<td>Architecture</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Urban Studies &amp; Planning</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics &amp; Astronautics</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Materials Science</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Nuclear Engineering</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ocean Engineering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>18</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>Humanities &amp; Social Sciences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Linguistics &amp; Philosophy</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Political Science</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>School of Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Biological Sciences</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Biology</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Earth, Atmospheric &amp; Planetary</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mathematics</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Physics</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Whitaker College</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Health Sciences &amp; Technology</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>133</td>
<td>55</td>
</tr>
</tbody>
</table>

Rec'd = Received, Ad = Admitted, Enrolled = Enrolled
TABLE XVI

MINORITY GRADUATE DEGREE RECIPIENTS
(September, February, June Degree Lists)

<table>
<thead>
<tr>
<th></th>
<th>Black American</th>
<th>Mexican American</th>
<th>Puerto Rican</th>
<th>American Indian</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master's Degree</td>
<td>34</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>Engineer's Degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Doctor's Degree</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Graduation Date</th>
<th>Master's Degree</th>
<th>Engineer's Degree</th>
<th>Doctor's Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BA  MA  PR  AI</td>
<td>BA  MA  PR  AI</td>
<td>BA  MA  PR  AI</td>
</tr>
<tr>
<td>September</td>
<td>2    2   1   0</td>
<td>0    0   0   0</td>
<td>0    2   0   0</td>
</tr>
<tr>
<td>February</td>
<td>6    4   2   0</td>
<td>0    0   0   0</td>
<td>0    0   0   0</td>
</tr>
<tr>
<td>June</td>
<td>26   1   1   1</td>
<td>0    0   0   0</td>
<td>6    0   0   0</td>
</tr>
<tr>
<td>Total</td>
<td>34   7   4   1</td>
<td>0    0   0   0</td>
<td>6    2   0   0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School</th>
<th>Master's</th>
<th>Engineer's</th>
<th>Doctor's</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture &amp; Planning</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Engineering</td>
<td>22</td>
<td>0</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Humanities &amp; Social Sciences</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Science</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

142
The Lowell Institute School (LIS) was established at MIT in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School continues this tradition by offering subjects in the areas of modern technology which are not readily available at other evening institutions. Entry-level courses require an adequate high school preparation, and the more advanced instruction is geared to the practicing technician who has an Associate degree or equivalent experience.

The programs of study range from single subjects designed to broaden job skill levels to comprehensive study of new technological areas in preparation for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who satisfactorily complete a course. In addition, students who complete a program of courses may earn a Certificate in Drafting Technology or a Certificate in Electronics Technology.

During 1986-87, LIS offered 34 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications, computer programming in BASIC and C, mechanical and electrical drafting, geometric dimensioning and tolerancing, mechanical computer aided design, printed circuit board design, blueprint reading, machine tools, metal joining, alarm technology, and housebuilding. In addition, refresher courses were offered in mathematics to support both the drafting and electronics curricula. New courses were introduced in architectural computer aided drafting, computer literacy, elementary calculus, engineering statics, gate arrays and cell based design, HVAC systems, and scientific glassblowing.

LIS admitted a total of 1,023 students to its courses in 1986-87. Of those enrolled, 77 percent successfully completed the certificate requirements. Among those who completed courses were 81 MIT employees. Sixteen students earned the Certificate in Electronics Technology, and five students the Certificate in Drafting Technology.

The past academic year has seen LIS expand its program of unique evening courses which no other Boston area school can match. The high percentage of students who successfully complete their courses indicates that both the subjects offered and the level of instruction are well matched to their needs.

BRUCE D. WEDLOCK
Special Summer Programs

The Summer Session Office administers an extensive series of one- and two-week special programs for professional men and women who wish to keep pace with developments in their fields. This activity has prospered each summer since its initiation in 1950. Current information on subjects and registrations are as follows:

Summer 1985 - 1,713 registrations in 65 special programs
Summer 1986 - 1,528 registrations in 62 special programs

Foreign citizens comprise approximately 11 percent of this registration.

Regular Subjects

Graduate students comprise 80 percent of the student body in summer. The 1986 registration of 3,178 students was an increase from 3,023 in 1985.

FREDERICK J. McGARRY
Upward Bound Program

The MIT/Wellesley Upward Bound Program is a year-round, coeducational, multi-racial, educational program for Cambridge high school youth. Now in its twentieth year, the Program serves 70 academically promising young men and women from disadvantaged backgrounds. The goal of Upward Bound is to motivate these youths to attend college, and to provide them with the skills necessary to succeed in college. To a large extent, the Program is influenced by the research done in the 1930's and '40's by social psychologist Kurt Lewin and his associates. The Program has met with good success (70 percent retention & 90 percent graduation rates) operating on the assumption that ego growth and academic performance are closely related. A developing ego needs to experience success in a warm and personal, structured environment to develop strongly, in both a personal and social sense. This development can be brought about through intervention outside of the family and school.

Upward Bound represents such an intervention. It has been established that the effects of failure can be reversed by presenting a young person with real success, and that further success leads to an increase in the student's level of aspiration. The Program staff are often the first to see real academic growth in the youngsters. Moreover, the staff, together with teachers and fellow students, play such a crucial role, because what students think they can do is dependent on what others think they can do. Thus, the students' perceptions of their abilities, and therefore what they will try to accomplish, are to a large extent, determined by the expectations of the staff.

Summer Program

The summer program, conducted in residence for six weeks on the Wellesley College campus, is designed to provide the student with an intense academic and social experience. Classes are team-taught by experienced high school teachers, students from Wellesley College and MIT, undergraduates and graduates, students from local colleges and universities, and Upward Bound alumni now attending college. Upward Bound students must enroll in three classes, each of which meets for an average of five and one-half hours per week, with three additional hours of supervised study, during the summer session. Additionally, students are assigned to tutorials whenever the need arises. Each student is required to take a mathematics, and English course and one science elective. Science courses include biology, physics, human physiology, computers and chemistry. The mathematics program includes review/enrichment sections for students who desire an additional review of or the introduction to secondary mathematics from basic arithmetic to calculus inclusive.

The Academic Year

The academic year program, while somewhat less intense due to its after-school format, is equally important. Building on the motivation and enthusiasm developed during the summer, the academic year program is designed to help the student cope with the myriad of academic, social, and family problems that confront him or her while in Cambridge. To achieve this, the following programs, staffed primarily by MIT or Wellesley College undergraduates, (We continually strive to increase participation by MIT and Wellesley College undergraduates through our continued involvement in the Wellesley College Teacher Certification Program and various outreach efforts.) have been developed and implemented:

Study Skills. The MIT Upward Bound office is open for study four days a week: Mondays, Tuesdays, and Thursdays from 3 to 6 p.m. and Wednesdays from 3 to 8 p.m. Tutors are on duty to provide homework supervision for both individuals and small groups. Tutors are typically MIT or Wellesley College undergraduates who meet regularly with core staff to discuss students' progress and/or difficulties.

Tutoring. Whenever requested or needed, tutors are assigned to individual students. These pairings meet on a regular basis at a specified day and time until it is mutually determined that the individual tutorials are no longer necessary. Organization and time management are stressed, as well as effective negotiation techniques. Lastly, SAT test preparation is available to the students from October to May on a weekly basis.

College Report, Class of 1987

Graduating seniors have enrolled in the following institutions: Morris Brown College, Westfield State College, North Carolina Central University, Morehouse College, Chamberlayne Jr. College.

Ronald S. Crichlow
AIR FORCE ROTC

The Air Force Reserve Officer Training Corps (AFROTC) program at MIT continues to provide challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts, and Wellesley. Year-end enrollment in AFROTC as of June 1987 was as follows:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Freshman</th>
<th>Sophomores</th>
<th>Juniors</th>
<th>Seniors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT</td>
<td>43</td>
<td>28</td>
<td>25</td>
<td>36</td>
<td>132</td>
</tr>
<tr>
<td>Harvard</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Tufts</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Wellesley</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52</strong></td>
<td><strong>38</strong></td>
<td><strong>34</strong></td>
<td><strong>51</strong></td>
<td><strong>175</strong></td>
</tr>
</tbody>
</table>

Besides providing opportunities for the development of leadership skills, the AFROTC program provided MIT cadets with over $1.5 million for tuition. Cadets from the other schools received tuition payments exceeding $0.7 million. Additional payments for textbooks and subsistence exceeded $0.25 million.

As in the past, several special cadet activities highlighted this year's training for AFROTC students. The Arnold Air Society (AAS) Squadron, a professional honorary service organization of AFROTC cadets, won its bid to host the 1988 national conclave for AAS. Other events included the Annual Tri-Service Awards Banquet, the Military Ball, Field Day, and the Annual Tri-Service Pass-in-Review. The year concluded with the traditional commissioning at the U.S.S. Constitution.

Fifty-one senior cadets received commissions as second lieutenants in the Air Force. Thirty of these chose to fulfill their military commitment in the Reserves. Seven lieutenants will go on to pilot training, one will train to become a navigator, and one will attend medical school.

Colonel Emmanuel J. Scivoletto, AFROTC Detachment Commander, completed his third year of dedicated service at MIT and will be replaced by Colonel Gary G. Nelson. Additionally, Captain Brian K. Mazerski, and Staff Sergeants Richard C. Shinn and Daniel F. Mazzucco were assigned to the detachment. Captain Robert G. Hussey and Staff Sergeant Larry D. Moody departed.

COLONEL EMMANUEL J. SCI VO LETTO, USAF

ARMY ROTC

The 1986-87 Academic Year was another productive one for the Army Reserve Officers' Training Corps (ROTC) program. Overall enrollment was maintained close to last year's total, which was the highest in the past five years. Over the academic year, a total of 91 students participated in our program, and at year's end, 87 of those students were still enrolled. MIT student participation showed an increase from 51 to 54 during the year, while Wellesley participation dropped from 14 to 7. We are particularly gratified at the increasing freshman enrollment, and look forward to the continuation of this upward trend. We have placed a massive emphasis on our awareness campaign for freshmen. We have found that there are a lot of incoming freshmen who have a basic interest in military service, yet, in past years they were not being made aware prior to college matriculation that when attending MIT, Harvard, Tufts or Wellesley, they could participate in our officer training program. Our mailing campaigns explain in detail what we have to offer and exactly how to go about enrolling in our program when they arrive. Responses to the mailings have been gratifying.

A breakout of year-end enrollment by year and institution is shown below.
Of the 54 MIT students enrolled, 46 are currently recipients of Army ROTC scholarships and five others have applied. These scholarships pay full tuition, a monthly allowance of $100, and a once-a-year textbook allowance of $370. The value of these scholarships to MIT for school year 1986-87 was $614,041. We anticipate that for school year 1987-88, approximately 45 MIT cadets will be on scholarship with a value to MIT of approximately $634,275.

This year the Army ROTC Department commissioned 25 new second lieutenants, 17 of whom were from MIT. Of the 25, four are entering medical school, eight others will be reporting immediately to active duty, nine are serving in the Army Reserve, two are staying at MIT to obtain their Master’s Degrees, and two others have a full academic year until they receive their MIT undergraduate degrees. We successfully met our commissioning mission from our higher headquarters of 18, but will fall short for school year 1987-88.

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 125 cadets receiving awards from 45 different organizations. Vice President Constantine Simonides and several other MIT representatives, along with representatives of the Tufts and Wellesley administrations, attended the banquet. The guest speaker was Professor Frederick J. McGarry who discussed some of the history of MIT and ROTC in the 1960’s and 1970’s. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, Field Day, other athletic competitions, the Annual Tri-Service Pass-in-Review and Parade, and the Tri-Service Commissioning Ceremony at the USS Constitution Museum with President Paul Gray participating.

On- and off-campus learning experiences continued to be expanded this year as cadets were given the opportunity to train on more Army weapons systems, were familiarized with more "state-of-the-art" systems, and were again flown from Briggs Field on MIT to Fort Devens, Massachusetts, in Army UH-1 helicopters. The MIT Student Chapter of the Society of American Military Engineers continued its growth, and participation continued strong in the MIT Pershing Rifles Company, a group of both ROTC and non-ROTC students dedicated to the pursuit of military tactical excellence and patriotism.

The ROTC Faculty Committee, under the chairmanship of Professor Robert MacMaster, continued to provide timely advice and support of the ROTC programs. Members of the committee, along with other members of the faculty and Lincoln Labs, participated in 19 scholarship boards throughout the year. The professional evaluation of scholarship potential rendered by members of the MIT community will be of great value to each applicant and to the Army.

Of the eight military members of the Army ROTC staff, there were four departures since last year, and four new arrivals. I have found this first year of mine as a member of the staff, after my years as a graduate student from 1970-72, to be rewarding, challenging, and exciting. I look forward to the continued development of this strong and vital programs.

LIEUTENANT COLONEL EDWARD D. HAMMOND

NAVY ROTC

Student enrollment as of September 1986:

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Sophomores</th>
<th>Junior</th>
<th>Seniors</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT</td>
<td>14</td>
<td>14</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Harvard</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Tufts</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Wellesley</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>22</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

Of the 25 Army ROTC Department commissioned 25 new second lieutenants, 17 of whom were from MIT. Of the 25, four are entering medical school, eight others will be reporting immediately to active duty, nine are serving in the Army Reserve, two are staying at MIT to obtain their Master’s Degrees, and two others have a full academic year until they receive their MIT undergraduate degrees. We successfully met our commissioning mission from our higher headquarters of 18, but will fall short for school year 1987-88.
<table>
<thead>
<tr>
<th></th>
<th>Freshman</th>
<th>Sophomores</th>
<th>Junior</th>
<th>Seniors</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT</td>
<td>34**</td>
<td>30</td>
<td>16</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Harvard</td>
<td>15</td>
<td>9</td>
<td>11</td>
<td>9</td>
<td>44</td>
</tr>
<tr>
<td>Tufts</td>
<td>12</td>
<td>2*</td>
<td>5</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td>Wellesley</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* Includes one non-scholarship college program midshipman attending Tufts University.
** Includes two non-scholarship college program midshipman attending the Institute.

On 2 June 1987, a Tri-Service Commissioning Ceremony was held in the U.S.S. Constitution Museum at the Charlestown Navy Yard, Boston, Massachusetts. Vice Admiral Walter T. Piotti, Jr. was the guest speaker. Of those commissioned, 31 were graduates of the NROTC program. Not included in the June commissionees is one commissioned January 1987, one in July 1987, and one anticipating an August 1987 commissioning.

Highlights of the year included:

1. An 11 day NROTC Freshman Orientation program at Fort Devens.
2. Visits in November 1986 by Rear Admiral Johanson, USCG, mess night guest speaker; and Brigadier General Grinalds, USMC, Marine Corps Birthday Ball guest speaker.
3. Field trips to Naval Air Station South Weymouth, Massachusetts and to Naval Education Training Center, Newport, Rhode Island.

Personnel changes included:

1. Commander James G. Ward relieved Captain Vincent P. McDonough as Commanding Officer and Visiting Professor of Naval Science.
2. Lieutenant Ralph E. Brunson relieved Lieutenant David E. Guza as Naval Ship Systems Instructor. Lieutenant Brunson is also scheduled to teach Seapower and Maritime Affairs.
4. Lieutenant Walter Scott Josephson IV relieved Lieutenant Kathy L. Callahan as Naval Science Instructor. Lieutenant Josephson is also scheduled to teach Naval Ship Systems I.
5. Yeoman Chief Petty Officer V. D. McLeod relieved Yeoman Chief Petty Officer J. M. Bailey as Administrative Officer.

A full year of Naval activities was conducted. High counseling and review board standards were maintained, and additional emphasis was placed on both individual leadership development and on physical fitness. It was again possible to provide volunteers with an opportunity to join the crew of foreign navy vessels. Also gratifying was obtaining assignment for two women commissionees, one with intelligence duty and the other with cryptology duty. The other commissionees selected nuclear power, aviation, and surface ship assignment with one selected for Engineering Duty Officer assignment. Two were selected for immediate postgraduate education and a third anticipated acceptance this summer.

COMMANDING OFFICER J. WARD
The MIT-Woods Hole Joint Program in Oceanography and Oceanographic Engineering continued to grow at a modest rate during 1986-87. The enrollment as of June 30, 1987 stood at 134 students. Sixteen doctoral degrees were awarded: two in Biological Oceanography, five in Chemical Oceanography, two in Marine Geology and Geophysics, six in Oceanographic Engineering and one in Physical Oceanography. Thirty subjects were given in conjunction with the Joint Program of which six were transmitted over the microwave link. There were 149 applications with 41 admissions to the Program.

A significant amount of effort was devoted to recruiting students into ocean studies. A two-day seminar series covering all oceanographic fields was given at MIT in November, primarily to inform MIT seniors about opportunities in oceanography. With support from the Office of Naval Research and some private resources of Woods Hole, a one-week program for 23 faculty from colleges with strong undergraduate programs in mathematics, physical and biological sciences or engineering was held in June at Woods Hole.

The use of the microwave link between MIT and Woods Hole continued to expand. It is now used extensively for joint subjects, and computers at the two institutions can now be linked with a high speed modem. The latter arrangement greatly facilitates much of the Program's joint research.

The Joint Program was fortunate to receive a $100,000 grant from Research Industries, Inc. for the purpose of promoting research in collaboration with the Bermuda Biological Station. Because of its convenient location Bermuda has had an important role in oceanographic research. This grant will encourage future efforts in this important region of the Atlantic Ocean.

ARTHUR B. BAGGEROER
Office of the Dean for Student Affairs

INTRODUCTION

Fiscal Year 1987 was once again an exciting and challenging year for the Office of the Dean for Student Affairs (ODSA). Productivity, enthusiasm, and comraderie among the staff were at an all-time high. This was all made possible by a diverse group of highly talented and energetic individuals working together to carry out a number of new and varied activities on behalf of students at the Institute. Changes in the Staff are described in the attached reports from the various ODSA sections and the Office of Minority Education (OME) and information on Affirmative Action Successes and Objectives is provided at the end of this introductory section.

I want to call attention to the extraordinary leadership David Wiley brought to the Undergraduate Academic Support section, albeit for only one year. While we are very pleased for David and for the Institute that he will be assuming the position of Registrar, effective July 1, we will miss his warmth and wit, as well as his high energy level.

James Tewhey has successfully met the challenges facing him in his first year as head of Residence and Campus Activities, the largest section of the ODSA. Jim's sense of humor and of fair play as well as his commitment to diversity all contribute to his strong leadership of the section.

Joyce Gibson, Director of OME, and Bob Randolph, Head of Student Assistance Services, continued to provide excellent leadership in their respective areas as well as sage advice to the new section heads and to me.

Mary Jasinski joined the ODSA as Staff Assistant this year, bringing with her extensive student contact and knowledge of the Institute from her former MIT positions in Athletics and the Registrar's Office.

Major Developments

Several significant developments took place in our area, including President Paul Gray's release of the report of the Minority Student Issues Group entitled "The Racial Climate on the MIT Campus." Many discussions and articles followed the report's release and a carefully prepared story by Susan Lewis on follow-up activities was included as an excerpt in the May/June 1987 Technology Review. The Racial Climate Report and the Freshman Initiatives Program were the major items discussed by the Visiting Committee on Student Affairs when it came to campus last November.

The results of the first year of the three-year Freshman Initiatives experiment are described in detail in the Undergraduate Academic Support report. However, I want to acknowledge the strong leadership and enormous energy provided by Travis Merritt and Robin Wagner during this year. We are particularly pleased that the tremendous success of the Freshman Advisor Seminars has led to an increase in their number from 8 to 32 next year.

The report of the Housemaster-Tutor Review Committee, chaired by Dean Gerald Wilson, was released in May following several months of discussion. Other members of the Committee were Professors and Housemasters Julian Beinart and Vernon Ingram; Mrs. Carol Hulsizer, former Housemaster; and Professor Arthur Smith. The report contains a number of important recommendations for strengthening faculty-student interaction and for improving the management of the Housemaster-Tutor Program (henceforth to be referred to as the Housemaster-Graduate Resident Program in keeping with the Committee's recommendations). The report has the strong endorsement and support of Provost John Deutch and steps have already been taken to begin the implementation of its major recommendations. Copies of the report, entitled "Toward A Greater Sense of Community," are available in the ODSA.

The Office is continuing to study quality of life issues as they relate to various student groups on campus. Task forces have been established that focus on Hispanic students and on Asian students, chaired respectively by Joyce Gibson and Bob Randolph. In addition, I am chairing a group of 15 to 20 people from around the Institute that is examining issues related to international students and visiting scholars. We are currently analyzing the results of a questionnaire completed by the departments and by a selected group of laboratories and centers regarding any special services they provide, or quality of life issues of which they are aware that relate to these groups. We are in the process of following up
the questionnaires with visits to the departments and expect to distribute a questionnaire this fall to a
subset of the international student population.

Affirmative Action Successes and Objectives

The ODSA continued to maintain a strong commitment to Affirmative Action during the year, with a staff
that was 27% minority and 27% male. The following table reflects the race/ethnicity and gender profile, as of March 31, among the 56 full- and part-time ODSA positions.

| ODSA AFFIRMATIVE ACTION PROFILE, FISCAL YEAR 1987 |
|---------------------------------|----------------|----------------|
|                                | Minorities     | Non-minorities |
| Admin & Other Academic Staff   |                |                |
| Male                           | 5              | 7              |
| Female                         | 6              | 18             |
| Subtotal                       | 11             | 25             |
| Support Staff                  |                |                |
| Male                           | 0              | 3              |
| Female                         | 4              | 13             |
| SUBTOTAL                       | 4              | 16             |
| TOTAL                          | 15             | 41             |

The five minority men in the administrative and other academic staff category include 3 Blacks, 1 Mexican American, and 1 Asian. The six minority women in this category include 5 who are Black and 1 who is Asian American. Not included in these numbers are the Dean-On-Call who is a Black male and a Native American female who serves as a consultant to OME on special projects.

The four minority females among the 20 support staff members are 2 Blacks, 1 Hispanic, and 1 Native American.

During Fiscal Year 1987 itself, minorities and males each represented 29% of the new full- and part-time persons hired. Our goal for Fiscal Year 1988 is to provide minority presence as professional staff in each of the Office's sections. A Black female has already been appointed as Assistant Dean in Residence and Campus Activities, effective next fiscal year, and two staff vacancies in the Undergraduate Academic Support section provide an opportunity to recruit the first minority professional staff to that section in recent years. By Fiscal Year 1989, the ODSA hopes to have at least one Asian American among the full-time Administrative staff.

An additional area of focus for Affirmative Action efforts in the next few years will be the Housemaster-Graduate Resident Program. Currently, there are no underrepresented minorities among the Housemasters and only a small number of the graduate residents belong to minority groups. This area is critical, given the findings of the Racial Climate Report, the extensive contact that persons in these positions have with students, and the major role these individuals play in setting the overall climate in their respective Houses.

We are confident that we can accomplish these goals. I am proud of the staff, and of their repeated demonstration that there is strength through diversity.

SHIRLEY M. MCBAY
UNDERGRADUATE ACADEMIC SUPPORT

The Undergraduate Academic Support (UAS) Office coordinates the freshman and undesignated sophomore advising programs, oversees the orientation programs for all new undergraduates, and serves as an academic information center for students, faculty members, and departments. The office also serves as the administrative support structure for the Faculty Committee on Academic Performance (CAP), Undergraduate Seminars, the January Independent Activities Period (IAP), and the Wellesley-MIT Exchange Program. The activities this year within the major UAS program areas are described below, and include a number of new initiatives.

Freshman Advising Program

The primary counseling of freshmen during 1986-87 was carried out by 243 advisors (127 faculty, 15 instructors/lecturers, 17 research staff members, 30 graduate students, and 54 members of the administrative staff). Supporting these advisors were 250 undergraduates who served as associate advisors.

The UAS and the Office of Minority Education coordinated and expanded their efforts this year to provide liaison between academic departments and freshman advisors to better inform advisors of the academic progress of freshmen enrolled in core courses. We also encouraged and helped departments in providing additional support for students experiencing difficulties.

Nine freshmen withdrew for a variety of personal reasons during the academic year. Eight additional freshmen were required to withdraw for at least one term because of unsatisfactory academic performance. Ways were developed this year to get better information from advisors in preparation for the end-of-term review of the freshman class by the CAP. The table below summarizes CAP actions over the past five years regarding unsatisfactory academic performance, as well as the number of the more informal UAS letters suggesting that the student review his or her performance.

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Required Withdrawals</th>
<th>CAP Warnings</th>
<th>UAS Letters</th>
<th>Total Academic Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-87</td>
<td>8</td>
<td>91</td>
<td>84</td>
<td>183</td>
</tr>
<tr>
<td>1985-86</td>
<td>10</td>
<td>94</td>
<td>73</td>
<td>177</td>
</tr>
<tr>
<td>1984-85</td>
<td>13</td>
<td>79</td>
<td>53</td>
<td>145</td>
</tr>
<tr>
<td>1983-84</td>
<td>12</td>
<td>96</td>
<td>89</td>
<td>197</td>
</tr>
<tr>
<td>1982-83</td>
<td>17</td>
<td>109</td>
<td>73</td>
<td>199</td>
</tr>
</tbody>
</table>

Undesignated Sophomore Advising Program

Twenty-six faculty and staff advisors counseled the 64 students who chose not to declare a major at the beginning of their sophomore year. By the spring term, the number of undesignated sophomores had decreased to 16. The respective fall and spring student figures for 1985-86 were 61 and 14.

Supervision and Coordination of Residence/Orientation (R/O)

The fall-term Residence/Orientation Program for all new undergraduates is produced almost entirely by students with support from the ODSA. This year's R/O program was coordinated by Hugo Ayala. Several changes were made last fall to better introduce new students to MIT and to each other, as well as to provide a better context in which they could make informed decisions. These changes included a longer orientation period before residence selection began, smaller welcome groups to provide R/O information, greater opportunities to explore the academic environment at MIT, and a Freshman Picnic focused on personal interaction among freshmen and other members of the MIT community. Other significant changes are planned for next fall to strengthen academic orientation and to streamline the residence selection process.

In late fall, at the initiation of the UAS, Associate Provost S. Jay Keyser formed a committee, chaired by Professor Thomas Allen of the Sloan School, to evaluate and improve the orientation of new students. The committee, composed of students, staff, and faculty, expects to complete its recommendations for residence selection and an expanded academic orientation by December 1987.

Administrative Support to the Committee on Academic Performance (CAP)

The CAP was chaired this year by Professor William Peake. During the year, the Committee handled approximately 400 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 61 Required Withdrawals (representing less than 2 percent of the undergraduates) and 348 Warnings (approximately 8 percent) were voted for the academic year, distributed by class as follows:
The Undergraduate Seminar Program

The addition of new seminars as part of the Freshman Initiatives (described below), as well as increased interest in regular seminars, resulted in high enrollments this year for Undergraduate Seminars. In the fall term 58 seminars were offered (an increase of 14), 15 of which were freshman advisor seminars or residence-based seminars; in the spring term there were 34 seminars (a decrease of 1 from the previous year), three of which were based in living groups. The number of students participating in the program increased again this year. Approximately 1,629 students (including 771 freshmen) enrolled in seminars, compared with 1,320 students (704 freshmen) last year. The seminars constitute a significant complement to the regular curriculum, and will expand significantly next year as the number of freshman advisor seminars increases.

Freshman Initiatives

The ODSA completed the first year of a three-year experimental program aimed both at strengthening the informal intellectual contact that freshmen have with faculty members and at improving the freshman advising system. Under the leadership of Professor Travis Merritt, Director of the Freshman Initiatives, the following five new programs were undertaken:

Freshman Advisor Seminars -- in which a faculty member advises up to eight freshmen and conducts for them a fall-term, six-unit seminar. Due to the unqualified success of this year's eight seminars, the program will be expanded next fall to offer 32 Advisor Seminars, which will serve about one-quarter of next year's freshman class.

Team Advising -- in which several advisors in close proximity within a laboratory or department meet periodically with their advisees to provide a larger support group and greater chance for social and intellectual interaction. This year, 16 teams involving 38 freshman advisors (half of whom were faculty members) advised about 150 freshmen. The reviews of the "team" approach were mixed, though individual members provided their own advisees with the usual attention as per "regular" freshman advising.

Living Group Advising -- in which some freshman advisors have their advisees and associate advisors residing in the same living group: 500 Memorial Drive and Baker House this year. The 500 Memorial Drive program differed from the older Baker House model by placing greater emphasis on monthly group meetings for Sunday brunches, which were well attended by both students and faculty. Both dormitories will sponsor residence-based advising next year.

Residence-based Seminars -- in which a faculty member leads a six-unit Undergraduate Seminar within a particular living group, with preference given to residents of the living group and to freshmen. The eight seminars offered last fall had a common theme, "Invention, Risk, and Responsibility." However, the intended joint activities proved too unwieldy, and the theme element of the program was dropped. While low fall enrollments resulted in the cancellation of three seminars, students rated their experiences in the seminars very highly. Three Residence-based Seminars were offered in the spring, with good freshman enrollments. Next year, about eight House Seminars will be held in the spring term only.

Faculty Associates -- in which faculty members agree to associate themselves with a particular living group, and are invited on a regular basis for dinner and informal discussion, primarily with freshmen. This program proved difficult to implement. Only about a third (15) of the MIT living groups expressed interest in having Faculty Associates. Six living groups -- 4 dormitories and 2 fraternities -- were successful in recruiting a total of 15 Faculty Associates. Next year, the responsibility for this program will be transferred to the Residence and Campus Activities section of the ODSA.

MIT Colloquium

Last year, the MIT Colloquium Committee was chaired by Professor Travis Merritt, and sponsored two full-scale events: "Ending Apartheid: Actions for Africa, America, and MIT" (co-sponsored by the MIT Corporation Joint Advisory Committee) and "Image Makers: Scientist, Engineer, Explorer." Both included keynote addresses and informal discussions within various living groups among the guests, faculty members, and students. The Committee is currently exploring the possibility of sponsoring a series of speeches during IAP '88 by presidential candidates on domestic and international priorities for science and technology.
Independent Activities Period (IAP)

Under the guidance of its new chairman, Professor David Gordon Wilson, the IAP Policy Committee set four specific objectives for IAP '87 and future IAPs: creating a focus on programs of interest to freshmen; encouraging departments to experiment with teaching methods and learning formats; stimulating Institute-wide activities; and promoting greater student-faculty interaction.

The first IAP Awards were established to applaud efforts to support the Committee's initiatives. Professor Reginald Newell, from Earth, Atmospheric, and Planetary Sciences, received the IAP Coordinator Award for increasing the number and quality of departmental programs. Dr. Alan Lazarus, from Physics, was honored for developing an intensive review which helped a number of freshmen pass 8.01. Marya Lieberman, a sophomore in Chemistry, received an award for organizing "A Novel Approach to Beginning Lab Work."

The number of IAP activities leveled out to 665 in IAP '87 (from 681 the previous year), with 27% faculty participation. A Registration Day survey of undergraduate IAP participation showed that about 27% are on campus before IAP begins, and 63% are here after the first week of IAP.

Wellesley-MIT Exchange

For the eighteenth year the Wellesley-MIT Exchange Program offered MIT and Wellesley students the opportunity to experience a different educational institution and to expand their academic programs through cross-registration.

The number of MIT students cross-registering for Wellesley subjects increased significantly over last year, while the number of Wellesley students taking MIT subjects dropped slightly. During the year, 467 MIT students registered for 494 subjects as compared with the 311 MIT students who took 354 Wellesley subjects the previous year. The number of Wellesley students cross-registering at MIT during the year was 359 in 414 subjects. Comparable numbers for the previous year were 363 students in 454 subjects. The increase in MIT cross-registrations is due primarily to the popularity of Wellesley subjects taught on the MIT campus, which this year included two courses in religion as well as both beginning and intermediate Japanese.

Three MIT students (two in mathematics and one in chemistry) earned certification as secondary school teachers through the Education Department at Wellesley. The Exchange Program continued to administer a small residence exchange program involving approximately six students from each school.

This was Professor Robert Silbey's sixth and final year as MIT co-chair of the Wellesley-MIT Joint Committee. He has ably fostered communication, cooperation, and collegiality between representatives of the two schools.

Academic Support and Information Center

Activities in this area are designed to improve advising and teaching programs for undergraduates. Examples of expanded or new efforts include the following:

1) Assisting the Graduate School Office in conducting the third annual orientation and workshop for new teaching assistants in Fall 1986.

2) Planning and implementing the Institute's first (in recent history) orientation workshop for new MIT faculty, held in September 1986. The faculty workshop was rated highly by the participants, and will likely continue as an annual event.

3) Sponsoring a number of study skills and time management programs during the fall and spring semesters and over IAP.

4) Working with the Minority Student Issues Group to prepare the report on the "Racial Climate at MIT" and to discuss the findings of the Black Alumni Survey with various groups of faculty, students, and staff.

5) Increasing the role of the Associate Advisor Steering Committee to include such new initiatives as (a) a highly successful first Academic Midway held in February, (b) using a "contract system" between associate advisors and faculty advisors as a way to strengthen the advisor-associate team, (c) updating last year's "Associate Advisor Guide," and (d) running a successful recruitment and training program this spring for more than 350 potential advisors.

6) Increasing the administrative support to Course Evaluation Guide by overseeing budget, providing fundraising assistance, and advising on editorial and technical aspects of the Guide.
Career and Course Orientation

With the assistance of an ad hoc faculty/staff committee, particular effort was devoted this year to acquainting freshmen with the broad spectrum of majors available to them. The goal of decreasing the number of new Course VI majors was achieved, thereby avoiding the need for admissions restrictions. The UAS prepared and distributed a booklet entitled "Major Explorations" aimed at dispelling current myths about MIT majors, and sent similar information to the parents of freshmen, asking for their support in encouraging students to explore the range of opportunities at MIT.

We continued to publish lists of departmental resources which help students explore majors and to provide resource information about departments and disciplines in the UAS Reading Room. We also assisted departments in the planning and coordination of spring-term departmental Open Houses.

To encourage freshmen to discuss choice of major with their instructors and advisors, the UAS coordinated a highly successful Freshman/Faculty Reception and Banquet on April 6, with the enthusiastic support of the Freshman Council and the Alumni Association. Following the dinner, a panel of successful alumni/ae from a wide range of fields discussed the relation of their MIT education to their eventual career paths.

General

UAS staff continued to serve on more than a dozen Institute committees. In particular, the Section Head kept the Office involved in the review of the undergraduate program by serving as a guest member on both the Faculty Policy Committee and the Committee on the Undergraduate Program. New procedures were implemented this year to streamline office operations and UAS programs.

Staff

Several staff changes occurred within the UAS during the year. David Wiley became Associate Dean and Section Head; as of July 1, he will assume the responsibilities as MIT's Registrar. Mary Enterline was named Assistant Dean, undertaking many new responsibilities, and Marie Danziger joined the staff as Assistant Dean. Susanna Hinds joined the staff, replacing Andrew Eisenmann who moved to the Residence and Campus Activities section. Elaine Konopka assumed the responsibilities of Maryglen Vincens, who is on a one-year leave-of-absence. Robin Wagner will be leaving to pursue further graduate study.

DAVID WILEY  JEFFREY MELDMAN
MARIE DANZIGER  TRAVIS MERRITT
MARY ENTERLINE  STEPHEN PATTERSON
SUSANNA HINDS  ROBIN WAGNER
ELAINE KONOPKA

STUDENT ASSISTANCE SERVICES

The year 1986-87 has been an extremely busy and rewarding one for the Student Assistance Services (SAS) section of the Office of the Dean for Student Affairs.

International Students' Office

The appointment of Milena Levak to the staff was especially important because it marked the changing of the guard in the international arena. Dean Eugene Chamberlain was a link to the development of the office in the post-war years, and with his retirement we lost a great resource.

Dean Levak's solid experience and broad perspective, coupled with the good work of Karen Zuffante, have provided strong and uninterrupted support to international students. Now the issues before us include improving services to international students and coping with and implementing the new regulations which are being put into effect by the Immigration and Naturalization Service.

The changing of the guard has allowed us the opportunity to look closely at international services at MIT. An International Issues Group has been formed by Dean McBay that draws upon resources from across the Institute to help identify services currently offered and those needed in the future.

Special Initiatives

The Class of 1990 contains the highest percentage of women of any class in the history of the Institute. In response to this new reality, SAS, through the leadership of Dean Jacqueline Simonis and
Lynn Roberson, Staff Assistant for Women Students' Interests, initiated and carried out a number of activities and programs. These included "Women as Role Models" (a series of faculty/staff panels), a successful workshop exploring issues related to professional women's confidence, and outreach to women's living groups on a variety of topics.

A new and very promising development was the creation of the Women Students' Cooperative Board. This advising group was created to give the SAS staff concerned with women students' issues support and insight as they fine-tuned their efforts on behalf of women. The group has been successful beyond expectations, and it is the first time there has been such a diverse group of students looking at the needs of women at MIT. Meetings have been well attended, and student interest is high. Coupled with the continued services of the Cheney Room Papers, the monthly publication focused on topics of interest to women at MIT, there is now in place a successful two-way means for identifying issues and needs, responding to them and publicizing relevant activities and responses.

A major concern in recent years has been with eating disorders. This year a network of MIT contacts knowledgeable about eating problems and known as "Net/Weight" was established. A new brochure, co-authored by Dean Simonis, was prepared to meet the need for easily accessible information about eating issues and support available. These efforts are possible because of our close working relationship with the Medical Department.

Dean Marilyn Braithwaite assumed primary responsibility for the programs for minority students and was able to successfully re-establish the Minority Discussion Group. In addition, she helped orchestrate increased support for minority students following the release of the Racial Climate Report. Dean Braithwaite also met with the Campus Police on issues raised in the Report.

Several members of this office were involved with the Minority Student Issues Group. There were others involved with the student group that dealt with similar issues. The release of the Racial Climate Report provided a number of opportunities for broadening communication among diverse groups in the community. Because this office sees a number of individual students, we were often able to anticipate concerns and step in before problems developed. Other activities in which we were involved include arranging for a lecture by Ishmael Reed, coordinating the Hill Award selection process and planning the year-end celebration for minority graduates and their families on commencement day. Plans for the fall include examining issues facing Asian American students at the Institute.

A very positive development this year has been the growing relationship between SAS and the Office of Minority Education. The new reporting structure and the renewed commitment toward cooperation has meant increased support for the diverse student groups which help to make this an exciting community.

Nightline continues to be a success story of which we can all be proud. It is an extension of the counseling function of the office, and its value is recognized by those aware of the number of crises to which it responds. Dean Simonis has done a fine job keeping up the enthusiasm of the group, while also improving the training of the student volunteers. In addition, new faculty support for Nightline has been recruited with the addition of two new faculty advisors. This year, guidelines describing advisors' responsibilities and support group procedures were developed and distributed. The result has been a clearer understanding of the goals, philosophy, and supervision of Nightline.

Dean Arnold Henderson has done an excellent job of providing staff support to the Faculty Committee on Discipline and helping both the students and the Committee deal with complex problems in numbers that exceeded those of recent years. He has also worked with several of the growing number of disabled students as they adjust to MIT. Members work closely with other committees such as the CAP, the Committee on Graduate School Policy, ROTC Advisory Committee, and the Advisory Committee on Women Students' Interests, etc.

Counseling Role

Finally, SAS is a counseling office. We have had 2,297 student visits over the year. Adding in the multitude of drop-in students and the continuing flow of international students, we see a substantial portion of the student body each year. Two suicides of enrolled students this year caused considerable grief, and SAS responded personally and programmatically. The growing concern with AIDS has taken planning time as we begin to develop programmatic responses with the Medical Department that will increase awareness of the danger, while at the same time modifying behavior.

In summary, SAS has once again dealt in a variety of issues that affect the human relations climate at MIT. It has been a year of challenge and a year of success. We have much more to do but an excellent staff, both support and administrative, makes the doing easier.
RESIDENCE AND CAMPUS ACTIVITIES

Undergraduate Housing

Crowding in the Institute Houses was significantly lower this year with 124 crowded rooms as opposed to 188 rooms last year. This reduction was due primarily to the smaller freshman class size and a slight decrease in the return rate of upperclassmen from 97% last year to 96%.

The incoming freshman class included 38% women, an all-time high for the Institute. The increased number of women students in recent years has resulted in an increased demand for single sex housing for women. Two steps were taken this year to further address this problem. First, the residents of MacGregor, the only all-male dormitory on campus, voted to go co-ed in the fall; and second, in several other houses the room assignment process will be adjusted to insure that women who request single-sex areas in those houses will be assigned to them. While these steps will assist in solving the problem for this Fall, additional steps, such as establishing a second all-female dormitory, will likely be necessary as the number of women students continues to increase.

Plans have also been made to improve the residence selection process for freshmen by eliminating "limbo," the brief, but often unsettling period when a small number of freshmen are uncertain of their final room assignments. This improvement should serve to decrease the anxieties of freshmen and their parents.

Graduate Student Housing

We were able to house only 27% of the graduate students on-campus again this year while the demand continued to hover around the 50% level. Without an upper limit on how long a graduate student can remain in on-campus housing, the turnover rate was quite low, resulting in the usual long waiting lists. At the initiation of the Graduate Student Council, a new plan was developed to limit tenure in certain spaces to one year as a means of creating additional turnover. By the year 1991, a pool of 400 one-year spaces for incoming students is expected to be available under this new plan.

Housemaster and Graduate Resident Program

The only change occurring among the Housemasters this year was the departure of Dr. Brian Harvey, Associate Housemaster at East Campus, to take a position at The University of California at Berkeley. Dr. and Mrs. Fernando Frimm, formerly graduate residents in Senior House, have been appointed to replace Dr. Harvey.

A major initiative this year was a review of the Housemaster/Graduate Resident Program by a committee chaired by Professor Gerald Wilson, Dean of the School of Engineering. The resulting report contained several recommendations designed (a) to foster continuing interactions between students and faculty through the residence system and (b) to improve and strengthen the management of the present system. Steps have already been taken to begin the implementation of the recommendations.

Fraternities/Sororities and Independent Living Groups

During the year "Community Behavior Guidelines" were developed to assist the Independent Living Groups in their relations with neighbors in Boston, Cambridge, and Brookline. Complaints declined and neighbors felt more comfortable knowing the students had accepted a role in policing themselves. Lounge space was found for the Alpha Chi Omega and Alpha Phi sororities when the Non-Resident Student Association space at 311 Memorial Drive became available. The first two floors have been remodeled to provide meeting space for these two women's groups. While this was a step forward, the lack of separate housing for the sororities remains a major problem.

Despite the smaller number of men in the freshman class, the fraternities had a very successful rush. This was accomplished by increasing the percentage of MIT freshman males entering fraternities from 44% in 1985-86 to 52% in 1986-87. The challenge of maintaining this high figure in the future is one of the main issues facing the fraternities.
Athena Deployment

Athena machines were deployed in three of the independent living groups during this academic year. Reports have been issued which indicate positive benefits, but not dramatically so. The costs of the program are high and the question of additional deployment has not yet been resolved.

Talbot House

This year marks the twentieth year of Talbot House as an MIT retreat facility. It continues to be a popular resource for our community. Talbot House was occupied for 164 days this year, with 58 separate groups enjoying the house and its environs. Over 1,400 individuals from MIT used the facility, including 1,014 students and 425 faculty, staff, and alumni.

Several major improvements were necessary this year in order to bring the building up to fire codes and to an acceptable maintenance level. As a result, the financial resources for Talbot House have been significantly reduced. The challenge for the future is to keep the facilities in good physical order while offering affordable rates for the MIT community.

Campus Activities

The Campus Activities program consisting of more than 200 recognized activities remains strong. The primary project of the year focused on the design for the renovation of the Student Center which will begin in August 1987. Faculty, students, and staff assisted with the planning, and several community and student groups were shown the proposed plans during the year. A major portion of the Student Center will be closed beginning this summer for the renovation project which is expected to last through the next academic year.

The Campus Activities office will be instituting a computerized scheduling program for West Campus Facilities this summer, after an intensive year-long planning process conducted by Steve Burke. We are hopeful that this program will result in greater efficiency in the scheduling process.

All permits for the use of alcohol by student groups and others are now funneled through the Campus Activities Office. With each permit issued, there is an accompanying education program involving the party organizers that includes information about the responsibilities and potential liabilities for those hosting the event. More education on alcohol use and abuse is needed.

Undergraduate Association (UA)

The UA expanded its sphere of influence during Bryan Moser's second term as UA President. The UA Council involved itself heavily in the undergraduate education reform discussion and it sponsored a week-long celebration of student life at MIT. Leadership development programs expanded to include retreat weekends for the UA, Student Center Committee, and the four class council executive boards.

Graduate Student Council (GSC)

The GSC saw another productive year in 1986-87. President Norman Wereley and the GSC Executive Committee are to be congratulated for a job well-done, despite lower than normal participation from the graduate student body.

Housing is still a highly-charged issue with graduate students. In October, the GSC participated in an Alumni Office telethon and in one evening raised over $18,000 towards new graduate housing. In addition to gaining Institute approval to modify the graduate housing tenure policy, approval was also obtained on a proposal to improve graduate student access to athletic facilities.

Perhaps the most significant accomplishment by the GSC this year was the release of the "GSC Survey Final Report" which analyzed data from a February 1986 survey. The survey queried graduate students on quality of life issues from housing to problems with advisors. Copies of the report were distributed in March to administrators and to all departments. Several departments have already utilized the information for presentations to their Visiting Committees. Also, the GSC document "Graduate Student Rights and Responsibilities" was formally approved by the Committee on Graduate School Policy.

An integrated plan to address the issue of adequate graduate student housing is now being developed and implemented. The renovation of Ashdown House basement, made possible in part by the Graduate Housing Reserve Fund, is underway and will provide 30 additional spaces. An existing industrial building in close proximity to the MIT campus will be rehabilitated to provide approximately 200 beds and will be ready for occupancy by 1990-91. Finally, a number of MIT-owned condominium units near the campus will be available for rental to current MIT graduate students.
Discipline and Harassment Cases

A report of student discipline and harassment cases for AY 1986-87, adjudicated by the Residence and Campus Activities staff, is available in the Office of the Dean for Student Affairs. In summary, two students were declared persona non grata, eleven were placed on Dean’s Office Probation, seven were given written warnings, eight were required to write letters of apology, and ten were required to carry out some form of public service. Several other cases were dealt with through verbal warnings.

Charges included assault and battery, verbal assault of a police officer, destruction of property, alcohol abuse, and disorderly conduct.

Staff Changes

Stephanie Diggs was appointed Assistant Dean, and will be joining the staff in July. Mark Ertel, Advisor to the Fraternities and Independent Living Groups, has resigned to accept an Assistant Dean's position at Jacksonville University. Andrew Eisenmann was promoted to Senior Staff Associate for Administration, and Ann Braden was promoted to Staff Associate for Residence Programs. Edward McCluney came aboard as Coordinator of the Student Art Association.

Attachments to the ODSA Report:
Fall 1986 Institute Graduate House Count
Fall 1986 Institute Undergraduate House Count

FALL 1986 INSTITUTE GRADUATE HOUSE COUNT

<table>
<thead>
<tr>
<th>SINGLE</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashdown</td>
<td>314 (82%)</td>
<td>70 (18%)</td>
<td>384 (100%)</td>
</tr>
<tr>
<td>Green</td>
<td>0 (0%)</td>
<td>43 (100%)</td>
<td>43 (100%)</td>
</tr>
<tr>
<td>Tang</td>
<td>342 (85%)</td>
<td>62 (15%)</td>
<td>404 (100%)</td>
</tr>
<tr>
<td>Graduate Residents</td>
<td>24 (55%)</td>
<td>20 (45%)</td>
<td>44 (100%)</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>680 (78%)</td>
<td>195 (22%)</td>
<td>875 (100%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MARRIED</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastgate*</td>
<td>176 (87%)</td>
<td>25 (13%)</td>
<td>201 (100%)</td>
</tr>
<tr>
<td>Westgate*</td>
<td>189 (90%)</td>
<td>22 (11%)</td>
<td>211 (100%)</td>
</tr>
<tr>
<td>Graduate Residents*</td>
<td>20 (80%)</td>
<td>5 (20%)</td>
<td>25 (100%)</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>385 (88%)</td>
<td>52 (12%)</td>
<td>437 (100%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1065 (81%)</td>
<td>247 (19%)</td>
<td>1312 (100%)</td>
</tr>
</tbody>
</table>

*There are 4 couples in Eastgate where both members are students, 2 in Westgate, and 2 Graduate Resident couples where both members are students.

Note: Total normal capacity of all MIT graduate residences is 1247. This number does not include graduate residents, and includes only one member of 2 student couples.
### FALL 1986 INSTITUTE UNDERGRADUATE HOUSE COUNT

<table>
<thead>
<tr>
<th>HOUSE</th>
<th>1 M</th>
<th>1 F</th>
<th>2 M</th>
<th>2 F</th>
<th>3 M</th>
<th>3 F</th>
<th>4 M</th>
<th>4 F</th>
<th>Other</th>
<th>TOTAL</th>
<th>CAP</th>
<th>VACANCIES</th>
<th>CROWDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>29</td>
<td>46</td>
<td>55</td>
<td>39</td>
<td>62</td>
<td>34</td>
<td>54</td>
<td>26</td>
<td>2</td>
<td>202</td>
<td>145</td>
<td>337</td>
<td>1</td>
</tr>
<tr>
<td>Bexley</td>
<td>10</td>
<td>12</td>
<td>21</td>
<td>6</td>
<td>25</td>
<td>12</td>
<td>23</td>
<td>11</td>
<td>1</td>
<td>80</td>
<td>41</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>Burton</td>
<td>37</td>
<td>51</td>
<td>59</td>
<td>25</td>
<td>58</td>
<td>35</td>
<td>68</td>
<td>35</td>
<td>1</td>
<td>222</td>
<td>146</td>
<td>368</td>
<td>4</td>
</tr>
<tr>
<td>East Campus</td>
<td>44</td>
<td>41</td>
<td>66</td>
<td>31</td>
<td>74</td>
<td>43</td>
<td>64</td>
<td>24</td>
<td></td>
<td>248</td>
<td>139</td>
<td>387</td>
<td>0</td>
</tr>
<tr>
<td>MacGregor</td>
<td>77</td>
<td>97</td>
<td>68</td>
<td>82</td>
<td></td>
<td>1</td>
<td>325</td>
<td>1</td>
<td>325</td>
<td>328</td>
<td>3</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>McCormick</td>
<td>54</td>
<td>51</td>
<td>72</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>238</td>
<td>238</td>
<td>219</td>
<td>19</td>
</tr>
<tr>
<td>New House</td>
<td>25</td>
<td>29</td>
<td>37</td>
<td>21</td>
<td>35</td>
<td>20</td>
<td>41</td>
<td>12</td>
<td></td>
<td>138</td>
<td>82</td>
<td>220</td>
<td>0</td>
</tr>
<tr>
<td>French House</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td>13</td>
<td>12</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>German House</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
<td>16</td>
<td>5</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Russian House</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td></td>
<td>9</td>
<td>10</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Spanish House</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>14</td>
<td>10</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Random</td>
<td>11</td>
<td>15</td>
<td>20</td>
<td>7</td>
<td>11</td>
<td>5</td>
<td>17</td>
<td>3</td>
<td>1</td>
<td>60</td>
<td>30</td>
<td>90</td>
<td>93</td>
</tr>
<tr>
<td>Senior House</td>
<td>9</td>
<td>14</td>
<td>29</td>
<td>28</td>
<td>38</td>
<td>15</td>
<td>40</td>
<td>6</td>
<td>1</td>
<td>117</td>
<td>63</td>
<td>180</td>
<td>183</td>
</tr>
<tr>
<td>500 Mem. Dr.</td>
<td>44</td>
<td>67</td>
<td>69</td>
<td>50</td>
<td>45</td>
<td>26</td>
<td>50</td>
<td>26</td>
<td>2</td>
<td>210</td>
<td>169</td>
<td>379</td>
<td>352</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>296</td>
<td>343</td>
<td>470</td>
<td>264</td>
<td>434</td>
<td>270</td>
<td>446</td>
<td>213</td>
<td>8</td>
<td>1654</td>
<td>1090</td>
<td>2744</td>
<td>2632</td>
</tr>
</tbody>
</table>

|                | 639 | 734 | 704 | 659 | 8   |     |     |     |       |       |     |           | 124    |
The 1986-87 year signaled greater visibility and participation of the Office of Minority Education (OME) in the life of the Institute. OME is now better known by more students, faculty, and staff, and its purpose better understood by the community at large.

Much of the staff's effort this year focused on developing stronger relationships with faculty and other support offices that provide services to enhance the undergraduate experience. New partnerships were developed and a foundation was laid to strengthen services to students. Ideas generated from these efforts have already proved beneficial to students and faculty.

Developing more contacts with professional organizations and maintaining company ties outside the Institute have also proved fruitful this year. These resources provided leadership development opportunities for students as well as access to scholarships and summer work options.

The visibility of the office was also influenced by the publication of the "Racial Climate Report" which, among other things, revealed the supportive role of OME in the lives of alumni. The Report identified experiences of minority students that frequently worked against their full involvement in the community.

Since the Report's publication, the OME staff has seen a heightened sense of awareness and interest in the plight of minority students by majority faculty and students. This awareness, of course, makes our jobs easier and helps to foster the partnerships necessary to address the existing problems.

The major events and accomplishments of the office are described below and details on all of the year's activities are available in the OME.

Office Move - The September move from 12-185 to 7-143 has had a major impact on accessibility of the office to students and the office's visibility within the community. The attractive architectural design of the office adds to the comfort of the work space for staff and students. An increase in student traffic this year is certainly due in part to the move.

Departmental Visits - During the year, the Director and Assistant Director held informational exchange meetings with undergraduate officers and administrative officers in 10 departments. Knowledge about how the academic departments interact with undergraduates is essential for OME's work with students.

Equally important is informing departmental staff about the purposes of the OME. These visits were the single most important activity of the year, and resulted in greater understanding of OME's role in the Institute. Visits to the remaining departments will resume in September in order to continue developing the partnerships and resources to assist students.

Visiting Scholars Program - This new program, made possible by a grant from DOW Chemical, brings distinguished scholars from underrepresented minority groups to the MIT campus. A typical itinerary includes individual meetings with some faculty and staff, a reception, and a public lecture. This format provides an opportunity for an exchange of ideas between the visitor and members of the community.

Dr. Mario Gonzalez, Professor of Electrical and Computer Engineering, and Associate Dean of Academic Affairs in the College of Engineering at University of Texas at Austin, was our first visiting scholar. His dynamic personality and style will be remembered by all who met him. His presentation, "Engineering Education and Minority Students in the 80's", offered insight and challenges which we must address more fully at MIT and in higher education in general. The success of this first event was very encouraging to the staff and student organizers. There are plans to invite two scholars annually beginning next year.

NACME Field Evaluation - A field visit from the National Action Council for Minorities in Engineering (NACME) was requested by the OME staff to evaluate our services to engineering students. MIT annually receives substantial student scholarship support from NACME, which has certain requirements for member schools to meet, including maintaining statistics on retention of scholars, and specific guidelines for addressing concerns of minority students. The OME support program exceeded requirements set by NACME and the office was praised for the comprehensiveness of its programs.

Hispanic Task Force - The first meeting of the Hispanic Task Force was held in May. The Task Force is charged with (1) identifying problems or areas of concern which affect the quality of life for Hispanic students, and (2) recommending specific actions to enhance and enrich their experience at MIT.

The group membership includes MIT faculty, administrators, and students, faculty from neighboring institutions, and community leaders. The task force will continue to meet next academic year.

OME Publications - An attractive brochure on the office was published for the first time this year; it helped improve the office's visibility within and outside MIT. The brochure describes the purpose of the office as well as its major activities. In addition to the brochure, a monthly newsletter describing
community events, containing reminders about Institute deadlines, and calling attention to activities specifically designed to attract minority students was sent to all underrepresented minority students.

Membership in AISES and SHPE - Contact with professional organizations which promote the interests of underrepresented minorities is important in developing opportunities for students. New memberships in the American Indian Science and Engineering Society (AISES) and the Society for Hispanic Professional Engineers (SHPE) have enlarged OME's network of resource people. These contacts have also provided scholarships and jobs for Hispanic and Native American students.

Scholarships - Working through OME, nine companies awarded over $10,000 in scholarships to minority students for use toward tuition. Several of the companies offered summer employment as well.

Student Advisory Committee - Under the leadership of the Assistant Director, the student advisory committee met monthly from November to May. This was the first year that full participation by all four underrepresented minority groups occurred.

This committee coordinated the visiting scholars program, worked on developing goals for the committee, and began to address the interests, needs, and concerns of organizations and cultures represented by the respective groups. The understanding and unity growing among the student leaders is positive and is expected to be of great assistance to the office in meeting its goals.

Faculty/Staff Advisory Committee - This group met during the fall and spring and had a fairly productive year. The most important accomplishments were (a) consensus to request formal recognition of the committee, (b) the establishment of major subcommittees and (c) participation of the Interphase subcommittee in the selection process for participants in Project Interphase.

Tutoring Program/SSAS - Under the leadership of the Assistant Director, participation in the office's major programs has increased over the last year. Advertising more broadly to the entire community was another 'visibility ploy' that resulted in greater student involvement. The fall term generates the heaviest student traffic in the office's Tutorial Program (TP). This year, 320 student visits were made to the TP, 190 in the fall, 130 in the spring.

Four seminars on Strategies and Secrets for Academic Success (SSAS) attracted 128 students for the year. For the first time, about one-third of the participants attending each session were non-minority.

The Upperclass-Freshman Buddy Program was dropped this year due to poor participation. It has been reorganized for next year and will use Interphase freshmen as buddies for non-Interphase freshmen.

Project Interphase - The 1986-87 Interphase program was quite successful. The first session enrolled 49 students and the second, 19. Professor John King, Assistant Professor Fannie Howe, and Steve Strang, Director of the Writing Program, were new additions to the faculty. New graduate student instructors were hired in mathematics, and some new tutors were added in all disciplines. A physics laboratory course was introduced and a Project Athena workshop was substituted for the computer science course. Student response to both changes was uniformly positive. Staff and student evaluations rated the program very favorably. The majority of the students also performed very well during the academic year, and believed their work during the academic year was positively influenced by their summer experience.

OME Staff

Activities of the OME staff are varied and numerous. The three administrative staff together have had over 500 contacts with students during the year. Donna Marie Horse Grant, a part-time consultant to the office, was instrumental in re-establishing the AISES student chapter, and in attracting Native American students to the office.

FALL 1986 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY STUDENTS

<table>
<thead>
<tr>
<th></th>
<th>American</th>
<th>Black</th>
<th>Hispanic</th>
<th>Total</th>
<th>All Students</th>
<th>Minority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>16</td>
<td>215</td>
<td>179</td>
<td>410</td>
<td>4443</td>
<td>9.2</td>
</tr>
<tr>
<td>Graduate</td>
<td>5</td>
<td>103</td>
<td>49</td>
<td>157</td>
<td>5313</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>318</td>
<td>228</td>
<td>567</td>
<td>9756</td>
<td>5.8</td>
</tr>
</tbody>
</table>

JOYCE T. GIBSON
TONY CANCHOLA-FLORES
DALLAS SLAWTER
Under the aegis of the Provost's Office, the Facilities Use Committee formulates and implements policy for the use of Institute facilities by recognized MIT groups. The Committee reports to the Associate Provost for Educational Programs and Policy. The Committee's members this year were Stephen D. Immerman, Director of the Campus Activities Complex; Doreen Morris, Special Assistant to the Provost; Ronald Suduiko, Special Assistant in the Office of the Chairman of the Corporation; Mary Morrissey, Director of Information Center; Barbara Fienmann, Campus Activities Advisor; Winston E. Flynn, Associate Registrar; Gayle Fitzgerald, Manager of Conference Services; Steven M. Burke, Administrative Assistant, Campus Activities, and Committee Chair Charlene Placido, Assistant Dean for Financial Affairs in the School of Science. The Committee generally meets weekly to review requests for the use of facilities and to discuss issues regarding policy, facilities charges, and related matters.

The Institute's tax-exempt status in part governs the use of MIT facilities. Facilities use should contribute to the enhancement of purposes for which the Institute has been chartered, with primary focus on its educational and research roles. MIT facilities may not be used directly to support candidates for public office or for lobbying for particular legislative issues, nor may the Institute's facilities be used to support profit-making organizations. The presentation by undergraduates of talks by candidates for public office is considered to be educational in nature, and therefore provision is made for the appearance of candidates for a variety of public offices.

The domain over which the committee presides includes all of the academic space at the Institute, the Julius A. Stratton Student Center, departmental memorial rooms, and all similar spaces. Inevitably the Provost's Office and the facilities committee are drawn into broader issues involving controversial potential use of MIT facilities. As a consequence, the Office of the Provost is frequently consulted on a wide range of political, social, and even religious issues stemming from facilities use. For example, the appropriateness of activities suggested for IAP in January of each year is reviewed by the special assistant to the Provost who frequently consults the Facilities Committee in addition to other appropriate sources within the Institute.

During the 1986-87 year, the Institute was host to: The Annual Logo Conference, Internoise 86, The Lisp and Functional Programming Conference, The New England Show Choir Camp, Computers in Cardiology 86, The Molecular Beam Epitaxy Workshop, The Fourth Annual Whitehead Institute Symposium, The International Association of Energy Economists Conference, a Symposium Honoring Massachusetts Institute of Technology Professor C. C. Lin, The Presbyterian Synod of the Northeast, and for the second year, The Massachusetts Special Olympics Summer Games. These events brought over 7,000 visitors to the Campus.
CHAIRMAN OF THE FACULTY

The Faculty Policy Committee

The Faculty Policy Committee considered a wide range of issues of significance to the Faculty. The Committee explored possible agenda items for 1986-87, including some topics continued from last year and new ones initiated at the beginning of the year. The FPC agreed to continue its practice of inviting the chairs of the Standing Faculty Committees to update the Committee on their activities. The Committee also reviewed reports and proposals relevant to the Faculty.

Professor Margaret L. A. MacVicar, Dean for Undergraduate Education, made three presentations on the efforts of the Committee on the Undergraduate Program. These included advance discussions of two proposals presented at the March and April Faculty Meetings (the Motion to Adjust the Humanities, Arts, and Social Sciences Component of the General Institute Requirements and the Motion to Establish a Minor in HASS); the formation of committees to coordinate faculty proposals for "Contexts" subjects and to review R/O Week; and an in-depth review of MIT's core curriculum.

The FPC participated in a discussion on The Racial Climate at MIT report and its meaning to the MIT community with Dr. Shirley M. McBay (Dean for Student Affairs), the report's authors, and some members of the Minority Student Issues Group. The report recommends that the Faculty Policy Committee "develop a statement of professional responsibilities for faculty with respect to racist behavior and racism, and consider ways to ensure its implementation." In response, a committee to be chaired by Professor Arthur C. Smith will be appointed to follow up, over a period of time, the report and its recommendations.

Another issue discussed by the FPC was MIT's current activities and future plans for coping with AIDS. The Director of the MIT Medical Department and one of its physicians, representatives from the Office of the Dean for Student Affairs, and the Special Assistant to the President (Dr. Mary P. Rowe) provided information about AIDS and helped the Committee examine questions about MIT's responsibility toward students and the community, not only in treating AIDS cases, but in preventing its spread. Because of the seriousness of the AIDS situation, the Committee agreed that the MIT community will have to think deeply about responses to the problem. Policies need to be developed to protect the rights of AIDS patients and those of the community as a whole. It is likely that this topic will be of continued concern to the FPC as well as the MIT community.

Professor Daniel M. Holland, Chair of the Ad Hoc Committee on Faculty Service (Tenure) presented preliminary findings and recommendations of this committee. The committee is charged with examining faculty retirement and other related issues and making recommendations regarding future policy on faculty tenure, and, more broadly, the terms of faculty service at MIT. The committee is concerned with maintaining a satisfactory and equitable process in the face of legal constraints and feels that offering incentives for older people to retire and perhaps making retirement a stage of the academic career process would be best for the Faculty and MIT. The Provost, who attended this meeting, added his comments. The FPC made several suggestions and indicated that it would like to see this topic discussed at a Faculty Meeting.

The Committee heard from Professor James A. Fay, Chair of the Committee on Faculty-Administration, on the proposed change in tenure rule (allowing eight rather than seven years to obtain tenure). Pros and cons of the proposed change were discussed, with opinion almost evenly divided.

President Paul E. Gray updated the FPC on the MIT Capital Campaign. The Committee discussed faculty involvement, which includes: soliciting ideas, helping to identify resources (individual and corporate), and helping to tie in the needs for student aid and endowed chairs to particular undertakings.

In addition to these major topics, the FPC conducted sessions on the following: 1) the new admissions procedures; 2) a proposal from a subgroup of the Committee on Student Affairs for a major program on "Mutual Respect at MIT" designed to "encourage the MIT Community to consider how perceptions of race, gender, nationality, sexual preference, and economic and political factors are formed by our background and self-perception;" 3) a proposal from a subcommittee of the Committee on Graduate School Policy to eliminate mentioning fields of study on diplomas; 4) the appropriate dissemination of The Statement of Graduate Student Rights and Responsibilities at MIT, a document initiated by the Graduate Student Council because of a concern that graduate students don't understand their rights and responsibilities at MIT; 5) overhead policy at MIT; 6) a proposal from the Committee on Industrial Liaison regarding research consortia and the distribution of funds to Faculty; 7) a report from the Committee on Privacy on the NCAA Drug Testing Program recommending that the Faculty examine MIT's interim statement and establish policy guidelines; and 8) an update on Phase II from the Committee on the Writing Requirement, with special attention to the status of seniors regarding the Requirement.
Other topics discussed more briefly throughout the year included collegiality, Course VI enrollment, and student demonstrations on apartheid and divestment issues.

The FPC anticipates that several of the issues discussed during 1986-87 will continue to be monitored by the Committee and that some will necessitate activity. New topics raised at its Year-End Meeting include women's housing issues, the new demographics at MIT, the state of junior faculty, and ethics at MIT. The presence of the Chair-Elect of the Faculty, Professor Bernard J. Frieden, on the Faculty Policy Committee for 1986-87 augurs well for a smooth transition to his two-year term.

Committee on the Undergraduate Program

The Committee on the Undergraduate Program (CUP), chaired by the Dean for Undergraduate Education, experienced an extremely busy and productive year. It set as its goal the exploration of the possibilities for an undergraduate program whose general features provide each MIT undergraduate -- in today's context -- with attitudes, habits of mind, and approaches to learning that ensure a lifetime of technical competence, social contribution, and personal fulfillment. CUP's immediate priority was the development of a framework for presenting a coherent picture of the proposed undergraduate requirements (i.e., MIT's general education component) to the community. The Committee also planned to charge a small group to examine the structure of the freshman year, with an eye to redesigning it.

During the summer, an intensive week-long meeting produced both a tentative framework and practical embodiment for the General Institute Requirements, pulling together threads from the reports and deliberations of the HASS and Science committees and the Engineering Commission as well as a sharper focus on the freshman year academic experience.

In the fall, CUP launched the reports of the Institute Committee on the Humanities, Arts, and Social Sciences Requirements (chaired by Professor Pauline Maier); the School of Science Education Committee (chaired by Professor Robert Silbey), which reviewed the science and mathematics component of the current General Institute Requirements; and the Commission on Engineering Undergraduate Education (chaired by Professor Jack Kerrebrock), which addressed the relationship of the Institute requirements and other features of the core undergraduate educational experience to engineering degree programs. The mailing of these reports to the Faculty began a process of broad discussion of the objectives and proposals contained in reports.

In January, an intensive three-day meeting was held to prepare CUP for making a statement to the Faculty about the specific directions MIT should take, and is exploring, in its undergraduate educational program. The Committee invited several guests to participate in discussions on "Contexts" courses; the Keniston integrative education "design team;" the freshman year; the Laboratory Requirement; the science core curriculum; the Chemistry, Mathematics, and Physics Requirements; and the HASS proposal.

CUP presented two proposals for a Faculty vote: a motion to adjust the Humanities, Arts, and Social Sciences (HASS) Component of the General Institute Requirements and a proposal to permit an optional Minor in HASS. The HASS Requirement proposal is "designed to promote increased breadth in a manner that complements the concentration component and to provide a more structured and intellectually coherent overall HASS Requirement." In response to faculty and student concerns, the vote on the HASS proposal was postponed until May, and CUP organized a series of Institute-wide events for debate and review of controversial aspects of the proposal. An amended version was then put forth and approved by a Faculty vote.

The proposal for an optional Minor in HASS for any student is a response "to needs expressed by persons in the School of Engineering for an experience in HASS which is more structured and more serious than that which most engineering undergraduates now have and by some faculty in SHSS for a larger constituency within the undergraduate engineering student body with a serious commitment to education in HASS." The proposal was also approved by a Faculty vote in May.

During the year, CUP: 1) endorsed the Dean for Undergraduate Education's plan to charge a committee, chaired by Professor Kenneth Manning, to examine the freshman year; 2) charged a working group, chaired by Professor Kenneth Keniston, to follow up on ideas from the Marx report on an integrative curriculum in the liberal arts and "to consider and recommend to the CUP, for its approval, a proposed set of institutional/structural features and changes constituting an educational experiment aimed at promoting the development of an integrative education for MIT undergraduates" (The Minor proposal was the first product of the Keniston effort.); 3) approved three proposals for "Contexts" courses transmitted by the School of Engineering Interschool Working Group on Contexts Subjects, chaired by Professor Elias Gyftopoulos; 4) discussed restructuring the Institute Laboratory Requirement to be based in departments; and 5) accepted and endorsed the report presented by Professor Leon Trilling on the Integrated Studies Program's proposals for future development and renewed ISP's experimental license for three years.
Throughout the year, CUP held discussions on the math-physics linking initiative, changes in admissions procedures at MIT, linking the Admissions Office with first-year instructors and providing more communication of admissions data, the three alternative programs (ESG, ISP, and Concourse), and student perspectives on educational policy and reform. CUP expects to continue its efforts in many of these same areas during the upcoming year.

Professors Pauline Maier, James Munkres, and Ed Roberts completed their terms. Student members Jonathan Gruber and Carey Rappaport finished their studies and graduated. Dr. David Wiley, Head of UASO; Mr. Michael Behnkke, Director of Admissions; and Mr. Bryan Moser, UAP, were Guests of CUP for 1986-87.

Other Faculty Committee Reports

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

Major agenda items and conclusions for the Committee on Academic Performance (CAP) for the past year have been: 1) Administrative measures are needed to encourage students to complete the Physical Education (and Writing) Requirement as intended rather than just before graduation; 2) the rules for completion of grades of I (Incomplete) should be enforced by the Committee, and students receiving I's should be informed of the rules; 3) procedures for readmission of students after a required withdrawal have been formalized to ensure interaction of the Student Assistance Service section, CAP, and the involved department.

The Committee on Curricula (COC), as usual, spent most of its time reviewing proposals from faculty for new and revised subjects and from students for substitutions in Institute Requirements. Upon the recommendation of the Dean of the School of Humanities, Arts, and Social Science, the Committee approved changes in units from nine to twelve for a large number of HASS subjects.

A few special issues were also addressed. Brief discussions were held concerning Institute Requirements for students returning after a leave of absence, and concerning criteria for allowing subjects to be taken more than once for credit. The COC chairman discussed the "7.01 problem" with Professor Graham Walker of the Biology department. Since 7.01 is offered only in the spring term, it has become a de facto freshman requirement, along with 5.12, for prospective biology majors. The COC's recommendation was that 7.01 be given both fall and spring terms. The Biology department decided to solve the problem another way, by deleting 7.01 as a departmental requirement.

The COC discussed, in consultation with Professor Kim Vandiver, the formulation of a policy concerning undergraduate seminars offered by instructors in ROTC programs. While not proposing that students should receive MIT credit for ROTC training, the Committee wished to recognize that certain ROTC subjects (e.g., 13S06/NS31, Coastal Piloting and Celestial Navigation) might be of interest to and suitable for non-ROTC students. To ensure that such subjects are sufficiently challenging, rigorous, and consistent with MIT standards, the Committee has requested that they be recommended and approved by an academic department head or school dean before being submitted to the COC.

The Committee on Discipline (COD) adjudicated a number of grievances against students brought to the Committee by members of the MIT community.

The Committee on Student Affairs (CSA) developed an outline for a proposed long-term Institute-wide program on mutual respect and discussed it with senior members of the administration. It suggests using several media and forums to help people consider how their views of other people are formed, along with the consequences of those views for all people at MIT. CSA has also prepared a report on ROTC matters, to be distributed during the summer of 1987. CSA sees several ways to intensify and improve administration and faculty interaction with the ROTC program, a step that would alleviate several recurring problems. Finally, consideration of the place of teaching assistants in the teaching environment is yet to converge. However, we are convinced that faculty members in charge of subjects can and should do much more to enhance the preparation of their teaching assistants.

During the past year, the Committee on Undergraduate Admissions and Financial Aid (CUAFA) 1) concentrated on marketing strategies and contributed to the development of a new brochure for recruitment; 2) implemented a modified selection process; 3) decided not to impose restrictions with respect to the choice of major on the freshman class entering in the fall of 1988; and 4) read freshman applications to learn more about the patterns of choice of major in the undergraduate population. In addition, there was a significant increase in minority admissions. The Committee began implementation of a new differential self-help program for low-income students.
For the Committee on the Writing Requirement, this past year has surely been the most exciting one since the Writing Requirement began in the fall of 1983. At the beginning of September, 1986, it appeared that about half of the members of the class of 1987 still had to complete the Writing Requirement. The routine of Phase One -- the Freshman Essay Evaluation, judging of five-page papers, and writing conferences -- paled by comparison.

We met the crisis head-on with a barrage of publicity and a series of alerts to department administrators, to advisors, and, of course, to the students themselves. These efforts succeeded. Over three hundred seniors submitted papers aimed at satisfying the Requirement within the two-week period from February 15 to March 1, the deadline for senior paper submissions. From that time on, we worked hard to assure that as many seniors as possible would manage to satisfy the Requirement in time to be graduated with their class. Not one senior was kept from being graduated solely because he or she had failed to complete the Writing Requirement.

Behind that statement lies a tremendous effort by many, many members of the MIT community: the Administration, the Faculty, the Committee and its Coordinator, administrators in every department, the Undergraduate Academic Support Office, all the staff of the Office of the Dean for Undergraduate Education, the Writing Program, the Writing and Communication Center, the Program in English as a Second Language, readers from inside and outside the Institute, the Registrar's Office, Physical Plant, Campus Police -- not to mention the seniors themselves. The jubilation felt at working together to help the seniors meet the Requirement remains with us.

The Committee has continued its work towards shifting primary responsibility for Phase Two to the departments in the fall of 1988. We have visited several departments to help them plan for this shift and will continue such meetings in the fall. The Committee also developed plans for the Phase Two review it will present to the Faculty in October, 1987. Finally, the Committee worked on refining its standards, an ongoing task that surely will form part of every year's efforts. We are very pleased with the way this year went and hope to maintain the same level of achievement with the class of 1988 and its successors.

The Committee on Faculty-Administration approved the final version of the changes to the portions of Policies and Procedures that treat the matter of disciplinary actions affecting faculty members. (Both the Committee and the Administration had discussed this matter during the previous academic year, but had not finally disposed of it.) The Committee met with the Provost to discuss a proposal to increase the maximum period of pre-tenure appointments to eight years, and it gave its qualified support to this proposal.

The Committee on Industrial Liaison has, by working closely with both the Institute's central Industrial Liaison Program and the Faculty's own liaison groups dispersed across campus, developed a much improved policy on the cooperation of the Liaison Program and the Faculty. We expect that the new arrangements will stimulate more effective relationships between the Faculty and industry, and we see this accomplishment as a really useful contribution to the prospective campaign.

The Committee on the Library System reviewed the activities of the Libraries during the previous year, using the Annual Report of the Director as a starting point. The Committee discussed the Visiting Committee meeting held in May, 1986, and the recommendations resulting from that meeting. Items of particular interest included automation, Rotch Library expansion, and the linkage of the Libraries with the developing campus network. The Committee focused on a number of topics of particular concern to the Libraries' users: copying machines, hours and access, and the physical maintenance of facilities. The Committee reviewed and approved the acquisitions budget. In the process of the review, considerable attention was given to the serious problem of escalating costs for scientific and technical periodicals and its impact on the overall library budget. The Committee reviewed data on the use of Hayden Library since it has been kept open extended hours and also discussed the impending transfer of responsibility for the Student Center Library from the Libraries to the Dean for Student Affairs.

Consideration of two related cases comprised the work of the Committee on Outside Professional Activities this year. Both concerned the request by senior research staff in the Harvard-MIT Division of Health Sciences and Technology that MIT assign patents on discoveries or devices developed in the Division to new companies established to develop and exploit those processes.

In the first situation, the Committee, working with the MIT Co-director of the Division, Dr. Roger Mark, and Professor Kenneth Smith, Vice President for Research, suggested a set of understandings and procedures designed to minimize future conflicts of interest and any untoward effects on Ph.D. students' education. These suggestions were in large part built on earlier guidelines developed by a Conflict of Interest Committee formed in 1985 by HST. The staff member concerned has agreed to proceed according to the proposed understandings. It is anticipated the second case will be handled similarly by HST.
Two observations may be made. The effectiveness of one of the agreed major understandings depends in large part on MIT's pursuit of a vigorous licensing policy; there was some uncertainty among the Committee as to whether this was a reliable assumption. Second, it would be useful to accumulate a body of MIT "common law" practice in such cases; the correspondence between the Committee and Dr. Mark hopefully is a start in this direction.

The Committee on Nominations presented its slate of elected members of the Faculty committees, including the Associate Chair of the Faculty, at the April Faculty Meeting, and filled vacancies in the elected membership as needed during the year.

In the fall of 1986, the James R. Killian, Jr. Faculty Achievement Award Selection Committee invited nominations from the MIT faculty and the Corporation for the James R. Killian, Jr. Faculty Achievement Award. A set of outstanding persons was recommended, and from these a short list was developed and additional documentation was gathered. The Committee selected Professor Jay W. Forrester as the recipient for 1987-88. Similarly, the Harold E. Edgerton Faculty Achievement Award Selection Committee named Sylvia T. Ceyer as the recipient for its award for 1987-88. Sincere appreciation is extended to the following faculty members for their special contributions and service as appointed chairs of the Standing and Special Faculty Committees during the past year: William T. Peake (Academic Performance), June L. Matthews (Curricula), John G. Kassakian (Discipline), James A. Fay (Faculty-Administration), Lawrence E. Susskind and Richard L. de Neufville (Industrial Liaison), Henry S. Marcus (Library System), Leon Trilling (Nominations), J. D. Nyhart (Outside Professional Activities), Alvin W. Drake (Student Affairs), Kenneth R. Manning (Undergraduate Admissions and Financial Aid), Kenneth M. Hoffman (Writing Requirement), John Ioannopoulos (Edgerton Award Selection Committee), and Henry D. Jacoby (Killian Award Selection Committee).

Mary C. Potter
Laura B. Mersky
Several events of the past year will influence the School's development in coming years. Important to note within the School are leadership changes and efforts to improve financial resources. New academic policies at the Institute also have an impact on the School's future.

Leadership transitions affect three divisions of the School. Professor Jack Myer completes his term as head of the Department of Architecture, and a search is underway for a new department head to be selected from the ranks of practitioners and educators outside the department. Professor William Porter agreed to act as Interim Head of the department. Professor Tunney Lee completed his first year as head of the Department of Urban Studies and Planning. Professor Stephen Benton assumes responsibility as director of the Media Arts and Sciences academic program. (Professor Nicholas Negroponte continues as director of the Media Laboratory.)

Two Institute initiatives affect the future direction of the School's academic program. The new humanities requirements for undergraduates present opportunities for the School to broaden and deepen its participation in undergraduate education. In addition the current review of the creative arts at MIT by a Provost-appointed committee has included an examination of the role of the School in visual studies. School members contributed to the deliberations of the committee; its recommendations are awaited with much interest.

In preparation for the Institute's forthcoming fundraising campaign, the School made substantial progress in promoting School contacts with alumni. The Dean and department heads addressed a gathering of alumni in Washington, D.C., which stimulated a regular meeting program of Capitol area alumni. In the Boston area, a series of breakfast meetings between faculty and alumni and friends of the School was begun this year and will be extended to other parts of the country in the coming year. The Department of Urban Studies and Planning began an evening seminar series for its Boston area alumni. The School lecture series, which attracts alumni, included talks by Professors Judith Wolin, Joanna Lombard, William Alonso, and author Michael Crichton.

In the area of sponsored research, the Media Laboratory registered major growth of 50 percent, achieving a program of $3.8M this fiscal year. The rest of the School, however, fell short of its goal of reaching an annual research level of $2M. School Council concluded a committee will examine the key research issues and recommend changes for Council consideration.

Facilities

The improvement of the physical facility upon which the School depends continues to have extremely high priority. Department of Architecture spaces are being improved on the fourth floors of Building N52 and Building 7. Following extensive study of alternative sites for the expansion of Rotch Library, the Institute reached a preliminary decision to adopt the "bookshelf" proposal that adds six or seven levels of stacks to the eastern edge of the existing library and renovates the existing spaces. The architect selection process is now underway.

An increase in the amount and capability of equipment and the appointment of Robert W. Smyser as lab manager in the Computer Resource Laboratory allowed a substantial increase in the number of students using computers in their educational programs.

Administration

Consolidation of administration and direction affected the School's newer programs. A new position was established for direction of the Media Arts and Sciences academic program, now designated as a section that will report to the Dean. The faculty associated with the Media Laboratory charted its academic development in connection with the pledge of a major gift from Nichidai Fund in Japan. The academic program in Real Estate Development was successfully reputed by the Committee on Graduate School Policy as provided in the creation of the Master of Science in Real Estate Development. A senior faculty committee drawn from the School departments and the Sloan School and the Department of Civil Engineering was created to provide oversight of the programs in the Center for Real Estate Development.

In the Dean's Office, Diane McLaughlin was appointed Assistant Dean for Administration, replacing Barbara Lister-James who had served the School for 13 years. Scott Campbell replaced Cynthia Ware as the editor of PLAN, the School's newsletter.
Faculty

Professor Bernard Frieden from the Department of Urban Studies and Planning was appointed as chairman of the faculty at MIT for the period 1987-89. Professor Stephen Benton was promoted to full professor. Tenure was awarded to Professor Anne Wagner of the History, Theory and Criticism program in the Department of Architecture. Promoted to Associate Professor are Professor Ranko Bon of the Department of Architecture and Professor Lynn Sagalyn of the Department of Urban Studies and Planning. Appointments to Professorship that began this past year include Assistant Professors William Hubbard and Frank Miller in the Department of Architecture and Lauren Benton in the Department of Urban Studies and Planning, and Assistant Professor Edith Ackermann and Associate Professors Edward Adelson and Alex Pentland in the Media Arts and Sciences program of the Department of Architecture.

Of particular significance during the year are the accomplishments of junior faculty in the School. Professor Bishwapyria Sanyal, noted for his outstanding work in evaluating assistance programs to Bangladesh, was appointed Ford International Career Development Professor. Professor William Hubbard received the Institute's J.H. and E.V. Wade Award which supports faculty research. Professor Ranko Bon's appointment as Macomber Professor was extended another year; his current work includes development of design for space structures. Professor Edith Ackermann was named the first holder of a career development chair in computers and education, which is endowed by the Fukutake Publishing Co., Ltd. of Japan.

Community Composition

Of the School's total enrollment of 579 students, 216 were women, 46 were minority, and 168 were from other countries. Last year we reported a total enrollment of 597 with 230 women, 49 minority, and 187 from other countries. The one remarkable change in student enrollments is a 30 percent increase of undergraduate students in the Department of Architecture.

In an aggressive recruitment effort backed by the commitment of Institute scholarship funds, the Department of Urban Studies and Planning more than tripled the number of minority students in the incoming class. In the coming year the Department of Architecture plans to match this effort with new recruitment initiatives.

Of the some 59 School faculty, nine are women and four are minority. One new woman faculty member was hired in the Media Arts and Sciences program of the Department of Architecture. At the level of lecturer, two minority members joined the School during the year, one in the Department of Architecture and one in the Department of Urban Studies and Planning.

JOHN de MONCHAUX
### STUDENT ENROLLMENT AND COMPOSITION 1986-1987

<table>
<thead>
<tr>
<th>Department of Architecture</th>
<th>Total</th>
<th>Women</th>
<th>Minority</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>90</td>
<td>42</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>M.Arch.</td>
<td>98</td>
<td>29</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>S.M.Arch.S.</td>
<td>64</td>
<td>18</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td>S.M.Vis.S./S.M. (unspecified)</td>
<td>47</td>
<td>18</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Ph.D. (resident)</td>
<td>29</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Total Graduate Resident</td>
<td>238</td>
<td>75</td>
<td>6</td>
<td>79</td>
</tr>
<tr>
<td>S.M. Real Estate Devel.</td>
<td>17</td>
<td>7</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Ph.D. (nonresident)</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Graduate Specials (nondegree)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ARCHITECTURE TOTALS</td>
<td>355</td>
<td>126</td>
<td>22</td>
<td>88</td>
</tr>
</tbody>
</table>

| Department of Urban Studies and Planning       |       |       |          |               |
| Undergraduate                                  | 4     | 0     | 0        | 0             |
| M.C.P.                                        | 79    | 32    | 11       | 24            |
| M.S.R.E.D.                                     | 36    | 13    | 3        | 0             |
| Joint M.C.P./M.Arch.                           | 11    | 4     | 0        | 9             |
| Ph.D. (resident)                               | 46    | 20    | 3        | 21            |
| Total Graduate Resident                        | 172   | 69    | 17       | 54            |
| Ph.D. (nonresident)                            | 35    | 18    | 5        | 15            |
| Special Students (nondegree)                   |       |       |          |               |
| SPURS                                          | 11    | 2     | 0        | 11            |
| CFP                                            | 2     | 1     | 2        | 0             |
| DUSP TOTALS                                    | 224   | 90    | 24       | 80            |

| School Totals                                  |       |       |          |               |
| Undergraduates                                 | 94    | 42    | 14       | 5             |
| Graduate                                       | 410   | 144   | 23       | 133           |
| Special Students                               | 75    | 30    | 9        | 30            |
| TOTAL ENROLLMENT                               | 579   | 216   | 46       | 168           |

* Two M.Arch. students (one registered in Course XI and one in S.M.Civil Engineering) and nine S.M.Arch.S. students (eight in Course XI and one in S.M. Civil Engineering) are not included here; one M.Arch. student (registered in S.M. Real Estate Development) and one S.M.Arch.S. student (in Course XI) are included.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Equivalent</td>
</tr>
<tr>
<td>Faculty</td>
<td>35</td>
<td>33.75</td>
</tr>
<tr>
<td>Other Academic Staff</td>
<td>39</td>
<td>30</td>
</tr>
<tr>
<td>Research Staff</td>
<td>22</td>
<td>16.25</td>
</tr>
<tr>
<td>Without Pay</td>
<td>19</td>
<td>15</td>
</tr>
</tbody>
</table>

| Studies and Planning      |           |           |
|                           | Total     | Equivalent| Women | Minority | Total     | Equivalent| Women | Minority |
| Faculty                   | 26        | 24        | 4     | 4        | 27        | 24.75     | 4     | 4        |
| Other Academic Staff      | 19        | 7.66      | 3     | 1        | 18        | 10.2      | 3     | 2        |
| Research Staff            | --        | --        | --    | --       | 1         | 1         | --    | --       |
| Without Pay               | 21        | --        | 9     | 3        | 10        | 7.7       | 5     | 5        |

| and Planning              |           |           |
|                           | Total     | Equivalent| Women | Minority | Total     | Equivalent| Women | Minority |
| Faculty                   | --        | --        | --    | --       | --        | --        | --    | --       |
| Other Academic Staff      | 2         | 1.75      | --    | --       | 1         | .20       | --    | --       |
| Research Staff            | 11        | 9.05      | 7     | --       | 7         | 5.25      | 3     | --       |
| Without Pay               | 14        | 4.35      | 3     | --       | 14        | 7.15      | 1     | --       |

|                           |           |           |
|                           | Total     | Equivalent| Women | Minority | Total     | Equivalent| Women | Minority |
| Faculty                   | 61        | 57.75     | 8     | 4        | 62        | 58.75     | 9     | 4        |
| Other Academic Staff      | 60        | 39.41     | 6     | 2        | 59        | 29.9      | 10    | 4        |
| Research Staff            | 33        | 25.30     | 13    | 1        | 21        | 18.35     | 5     | --       |
| Without Pay               | 54        | 19.35     | 13    | 3        | 39        | 28.85     | 9     | 5        |
A number of important initiatives begun in Professor John Myer's tenure as Department Head were realized in this academic year.

First, two important steps were taken toward achievement of department policy to increase diversity in design teaching in the professional (MArch) program. Two new faculty members, Professors Erich Schneider-Wessling and William Hubbard, who were identified in an international search process conducted in 1985-86, began their appointments in the department this year. In addition to the new permanent design faculty, a Distinguished Visitors Studio for advanced students was taught for the first time in the fall. The studio, which will be a continuing feature of the design curriculum, was taught in sequence by three internationally renowned practitioners: Professor Gottfried Böhlm, winner of the 1986 Pritzker Prize in Architecture; Guenther Behnisch, architect of the Munich Olympic Village, also from Cologne; and Judith Chafee, from Phoenix, Arizona, who among other honors has had three AIA Record House Annual Awards. Presence of the new faculty was a catalyst to the program and added greatly to the general exchange, as evidenced in overall excellent studio results shown in spring final reviews.

Second, an important objective has been realized in the reformulation of the building technology group. The search for a senior faculty member to teach and direct research in the technology of buildings concluded in the appointment of Leon R. Glicksman, formerly Senior Research Scientist in Mechanical Engineering, as Professor with permanent tenure in this department. He will direct an interdisciplinary program with Civil and Mechanical Engineering for masters and ultimately doctoral candidates in the technology of buildings. We believe that the program will be among the first university-based programs to address important issues of advanced technology with respect to the overall building environment. Searches to fill two junior faculty positions will be begun in summer 1987: one to focus in engineering research areas, the second with expertise in current architectural technology to contribute to the professional (MArch) curriculum. Addition of these two will complete the faculty complement in building technology, creating the range of skills necessary to conduct leading-edge technological research in our second master's program (SMArchS) and to provide complete training in state-of-the-art technology within the professional program.

An important increase in the number of undergraduate majors in Architecture this year presents a challenge that will demand serious department attention in the near future. In AY 1982-83 through AY 1985-86, the number of undergraduates enrolled in this department hovered around 70, but in AY 1986-87, it jumped to 90. Moreover, while about 70 students each of the four years registered for the first introductory subject, 4.01 Issues in Architecture, we (correctly) anticipated a larger demand by offering the subject for the first time in both fall and spring. Even then we could not meet the combined demand of about 130 students. Further, in May 1987, 35 freshmen selected Course IV, as opposed to a maximum of 15 in each of the four previous years. We must therefore conclude that the number of undergraduates in the department will continue to increase substantially.

Though more undergraduate majors have been actively sought and welcomed—strategies to increase undergraduate enrollment were an approved part of past Five Year Plans—the department finds its resources seriously strained, particularly in covering the teaching of introductory and architectural studio subjects. The balance between educational quality, budget and undergraduate growth needs to be carefully watched over the next several years. The possibility of steps that would either reduce undergraduate growth or increase Institute support need to be considered. Professor William Porter chaired a committee of senior faculty from a number of department programs who worked to formulate curriculum reorganization which will better serve our increasing undergraduate population and maximize the use of available department resources for that purpose.

In a meeting of School Council this spring, it was resolved that Media Arts and Sciences should be given separate status as a section, detached from the Department of Architecture, and required to report directly to the Dean of the School of Architecture and Planning. It is expected that members of the department will play a role in the Institute overseeing policy committee to be established in the beginning of the next academic year.

After five years of service, Professor Myer has this year announced his intention to step down as Department Head, effective August 31, 1987. He will spend a sabbatical year in architectural practice before resuming his position on the architectural design faculty. It has been determined that the next Department Head should be from outside the present faculty and a search is now underway. The search committee named by Dean John de Monchaux is chaired by Professor Ronald Lewcock. Professors Ranko Bon, Imre Halasz, Henry Millon, Jan Wampler and Anne Wagner are members. Professor Porter has agreed to serve as Interim Department Head for one year until the search is concluded.
In 1986-87 the department had a total of 328 regular students including 10 non-resident and special students and 17 students in the Real Estate Program who registered in this department. Enrollments in PhD (29), SMArchS (64), and MScVS (47) remained relatively stable; March numbers rose to 98, returning after a two-year downturn to steady state for the program of about 100 students; and BSAD enrollments showed marked increase (from 72 to 90). Of the total student population, 32 percent are women, 3 percent are minority, and about 31 percent are international students. There were 523 applications for admission to the department for fall 1987 and 152 offers of admission.

**Master of Architecture (March)**

There was an increase in applications to the March program again this year. Of the 236 students applying, 46 were offered admission, of whom 10 were MIT undergraduates. Acceptance of admission by first-round choices remained high and the number of MIT undergraduates electing to continue their professional education here continued to rise.

Professor Porter chaired the March/BSAD committee this year. Faculty members were Professors Bon, Schneider-Wessling, and Maurice Smith; student members were Sara Haga, Pierre Leclerc, and Ken Radtkey. Their weekly meetings resulted in proposals to the Head on design studio staffing and the process for student choice of studio; building technology curriculum in the professional program. A second group, the Quality of Life Committee, was active for the first time this year. Made up of professional program students and advised by Professor Wampler, the committee concerned itself with program and space management issues. Under the committee's aegis a Forum on the Future of the Architecture Department was organized in April 1987. The seminar convened department faculty and students for an all-day discussion of the professional program and the broad direction of the department over the next ten years.

The Quality of Life committee has also taken the lead in the planning and construction of improvements to department studio space. A student-designed print shop was built during IAP and in June in space adjoining the Old X. A one-week sketch problem competition for all architectural program students at the outset of the second semester yielded plans for the renovation of the Level I studio space on the fourth floor of building seven. Student team entries were juried by Dean de Monchaux, Professor Myer, Physical Plant Director Paul Barrett, Boston architect Yusing Jung (March '62), and Professors Wampler and Smith. Schemes by two teams were selected for further development; the scheme finally chosen from the two was put into design development during the summer of 1987, and fundraising for support of construction is underway.

As noted above, this year saw important gains on department policy to increase appropriate diversity in design studio teaching. The two new permanent faculty each taught design studios--Schneider-Wessling at Level II-III, Hubbard at Level I—and Professor Hubbard directed the spring section of 4.01, which met with an enthusiastic student and faculty response. The Distinguished Visitors Studio was offered at Level III.

The department lecture committee organized an excellent series in AY 1986-87. Among the speakers in the fall term were our distinguished visitors, Professors BHjm, Behnisch, and Chafee, Lebeus Woods, Alex Tzonis and Tadao Ando. The spring series featured Rijk Rietveld and Herman Hertzberger.

Awards to students in the professional program were as follows: the William Everett Chamberlain Prize to Herman Ferre III (BSAD '87), for achievement in architectural design; the Sidney B. Karofsky ('37) Prize to the outstanding March student entering the final year of study to Denise Henrich; the Francis Ward Chandler Prize for achievement in architectural design to graduating March students Julia Bernert, Josefina Garcia Marquez, and Gregory Faulkner; the Alpha Rho Chi Medal for promise of professional merit to Heidi Johnson (March '87); the AIA Certificate of Merit to the second-ranked March student to Niccolo Casewit, and the AIA Medal, for the top-ranking graduate student in the department to Barry Stanton.

**Master of Science in Architecture Studies (SMArchS)**

In 1986-87 there were 78 students in the SMArchS program: 21 concentrating in Environmental Design, 17 in Design and Housing, 15 in Building Systems Design, 15 in Design for Islamic Cultures, 8 in History, Theory and Criticism and two in general studies. The first students from the Aga Khan Program's Design for Islamic Cultures section received degrees in June 1987.

Research and inquiry is the foundation of the SMArchS program. Consistent with the purpose to balance class format learning with the opportunity for students to participate in investigations, the program maintained a wide variety of research projects this year.

Professor Nabeel Hamdi and Principal Research Associate Reinhard Goethert continued their work with the National Housing Development Authority of Sri Lanka on general policies concerning that government's Million Houses Program. Again this year, they organized and directed the Special Interest Group on Urban Settlements (SIGUS) which presented a series of three one-week events during the spring term. Guest faculty from funding agencies, government and practice were invited to MIT to participate in two workshops—Design of Refuge Resettlement, Public/Private Partnership Building Equity in Low Income Housing—and a symposium...
First World Problems/Third World Solutions—which commemorated the International Year of Shelter for the Homeless. Last August as part of the Professional Practice Program the Housing Group organized a two-week seminar and workshop for the Biennial International Shelter Workshop series. Titled "Beyond the Year of Shelter", the course was attended by some 40 participants from various levels of government, practice and research establishments, representing some 17 different countries.

Professor Bon began a new research project, with Michael Joroff of the Laboratory for Architecture and Planning, on real property management. In the fall term, Professor Bon and three SMArchS students from the Building Technology Group organized a space station design workshop. The subject attracted a large number of students from across the Institute and involved a number of MIT alumni active in the space industry.

This spring the Aga Khan Program offered a design studio focused on Istanbul and the redevelopment of the Golden Horn. Directed by Professor Lewcock and Research Associate Aktar Badshah, it included a two-week field trip to Istanbul and a two-week practical building workshop during which students were introduced to traditional building methods and materials.

Professor Eric Dluhosch travelled to Cairo this spring to initiate the second phase of his project in The Improvement of Performance of Egyptian Prefabrication Housing Factories. He also began the second phase of his Masonry Compute research for the International Masonry Institute. Lecturer Dennis Frenchman conducted a one-day seminar, MIT Charette in the Snow: A Winter Place, at the Boston Center for the Arts last spring. The Environmental Design Group continued its series of forums with speakers including Lebbeus Woods, Peter Droege, and Jeffrey Heller.

Two SMArchS students received awards this year: Howyda Al-Harithy ('87) received the Best SMArchS Student Award, and Henry Kwan ('87) received the fourth annual Marvin E. Goody Prize in the Building Arts.

Master of Science in Visual Studies (MSVS)

There were 37 MS students enrolled in the Media Laboratory program, 10 MSVS students in the Center for Advanced Visual Studies. Reports of these programs are made separately within the School of Architecture and Planning report.

PhD

PhD students in the department totalled 37: 10 resident and eight non-resident in the History, Theory and Criticism of Architecture (HTC) section, two in general studies, and 17 resident in the Media Laboratory.

Again this year the PhD Forum presented a list of distinguished scholars who led seminars for the HTC group, including Anthony Vidler, Isabelle Gournay, David Brett, Nancy Stieber, Lisa Reitzes, Robin Evans, Stephen Gardner, Mark Jarzombek.

Awards and activities of HTC doctoral students include the MIT 1987 Carroll L. Wilson Award to Ikemefuna Okoye, a Canadian Government Grant to Rejean Legault, and the first annual Boston Chapter Construction Specifications Institute Award for Excellence in Construction Technology to Robert Pietroforte. K. Michael Hays served as co-editor of the MIT Press journal, Assemblages.

FACULTY

Visiting faculty in architectural design were Klaus Steffan, from Munich, who assisted Professor Schneider-Wessling; Stefan Bühm, who shared studio teaching responsibilities with his father, Gottfried Bühm; Renee Chow (March '80) who taught a section of Level I in the fall term; and David C.S. Folk, Visiting Professor from the University of Pennsylvania, who directed a section of Level I in spring. In the HTC section, Professor Richard Pommer from Vassar taught a subject titled "Mies van der Rohe and Modernist Architecture" this fall; Professor Carlo Olmo from the Polytechnic Turin taught "History of the Industrial City", and John Pinto, Chairman of the Smith College Department of Art, taught "Architects and Antiquity: Alberti to Piranesi" in the spring term.

New faculty in the department in academic year 1986-87: Frank Miller, named Assistant Professor of Computer-Aided Architectural Design; James Anderson, Lecturer in Computer-Aided Architectural Design; William Hubbard, Assistant Professor of Architecture; Erich Schneider-Wessling, Visiting Professor of Architecture; Thomas Chastain, Lecturer in Architecture, and Richard Rush, Lecturer in Building Technology.

Professor Bon was promoted to the rank of Associate Professor. Professor Wagner was promoted to Associate Professor with permanent tenure. Professor Robert Slattery resigned this year, and Professor Chester Sprague retired effective February 1, 1987.

In the Media Laboratory, Professor Stephen Benton was promoted to the rank of full professor and named chairman of the Media Arts and Sciences academic program. Professor Edith Ackerman was named first holder of a career development chair in computers and education endowed by the Fukutake Publishing Co., Ltd.
of Okayama, Japan. Two new faculty joined the Laboratory: Professor Edward Adelson, Associate Professor of Media Sciences and Professor Alex Pentland, Associate Professor of Computers, Communication, and Design Technology.

There were a number of honors and awards made to department faculty in 1986-87. The firm of Imre & Anthony Halasz received a state-wide award in the first annual Governor's Design Awards for the design of St. John of Damascus Church in Dedham; the Harvard Square Garage, by Professor Myer in association with Professor Rosemary Grimshaw, received a regional citation. Professor Wampler was again honored for his design of the Angela Westover House in Jamaica Plain with the 1986 design award from the New England Regional Council of the American Institute of Architects. Through MIT Professor William Hubbard was granted the J.H. and E.V. Wade Award which provides support for research especially for junior faculty.

Finally, Professor Myer has this year joined the Cambridge architectural firm of Linea 5 where he will be a senior partner in association with Professor Grimshaw and Michael Slezak (MArch '78).

JOHN R. MYER
INTRODUCTION

This was a year of transition. After four years of significant accomplishment, Professor Gary Hack stepped down as Head of the Department to be succeeded by Professor Tunney Lee, returning from service in the Massachusetts state government. Some of the innovations Professor Hack had put into place were the Developing Areas option in the Master of City Planning program, the establishment of the Center for Real Estate Development, and the consolidation of the Ph.D. program into a smaller, more focused one. He identified financial aid and declining applications (especially from minorities) as significant problems to be addressed.

However, the field of urban planning is inextricably linked with the size of the government's role in social welfare and in controlling private development. In the 1960's, the Federal government spent large sums of money on urban renewal, housing and community services while foundations also contributed heavily to programs aimed at minorities and urban areas. That heavy emphasis declined steadily through the 1970's and has reached its low point in the Reagan administration. The department expanded significantly in the early 1970's to include new areas of study and new faculty from other fields, especially the social sciences. Applications rose and an aggressive recruiting campaign with sufficient financial resources brought to M.I.T. a large number of minority students into both the Master of City Planning (M.C.P.) and Ph.D. programs. Many of those students have gone on to teaching, research and practice and have made significant contributions to the profession and urban communities. But despite our best efforts, the number of minority students declined dramatically until this year.

This year may mark the reversal of the trend. The decline in the governmental role did not mean that urban problems went away. On the contrary, they have become more severe for some parts of the population and some parts of the world. One of the hopeful trends has been the willingness of state and local governments to take up some of the federal role. As a result, the demand for planners has been at its highest in a decade and starting salaries have risen correspondingly.

With the world changing in our direction, the department has made initiatives in several areas. One of the first successes has been in minority recruitment where the combination of financial aid from the Institute and energetic recruiting efforts by Lecturer Tom Stokes has more than tripled the number of minority students from 6 last year to 21 in the incoming class. The department has also begun efforts to identify areas of common interest and strength among the faculty, to reexamine our curriculum and teaching methods and to build research in order to help solve the problems created by urbanization both in the U.S. and in the developing world.

EDUCATIONAL PROGRAMS

The Master of City Planning (M.C.P.) program remains the core of the department with all applications rising along with a significant increase in minority students accepted. This year there were 42 graduates entering a very favorable job market (mostly in the public sector), in which demand exceeded supply and in which starting salaries have improved considerably. Despite the improvement, public sector salaries are lower than private sector, and the profession must continue to attract young people with a devotion to public service. Therefore, the increasing gap between tuition and financial aid will continue to be a deterrent to potential applicants. Professor Phillip Clay directed the M.C.P. program.

The Ph.D. program continues its efforts to stabilize the program to assure a greater level of faculty contact with students and has succeeded. This June, eight students received their Ph.D. degrees which is the largest in recent years. Professor Langley Keyes directed the Ph.D. program.

The Community Fellows Program, under the direction of Adjunct Professor Mel King, hosted three Fellows: Fred Dow, Solangel Rodriguez and Takako Salvi. The program sponsored the visit and videotape of COMADRES (Committee of Mothers and Relatives of Political Prisoners, Disappeared and Assassinated in El Salvador).

The Special Program for Urban and Regional Studies of Developing Areas (SPURS), under the direction of Professor Lloyd Rodwin (Fall) and Senior Lecturer Alan Strout (Spring) enrolled a total of eleven Fellows and two Associates. The eleven Fellows represented ten countries: Argentina, Brazil, India, Israel, Italy, Republic of Korea, Nepal, Philippines (2) and the Republic of South Africa. All but two will be rejoining their old organizations. Of the two, one will be pursuing professional interests in Europe and the other will be pursuing a Ph.D. at Harvard. The two SPURS Associates this year were Antonio
Azpurua, a Venezuelan architect and recent student in France and DUSP, and Professor Bertha Becker from the Getulio Vargas Foundation's Institute of Public and Political Science (Brazil).

Student Awards:
Lisa Grollman was awarded the American Institute of Certified Planners' Outstanding Student Award; Omar Razzaz won the Stephenson Award. Scott Soloway received the Urban Land Institute Award and Todd McGrath won the $10,000.00 first prize in an essay competition sponsored by the Shidler Group, both in national competitions. Leila Zlaoui (M.C.P. '87) will be pursuing her Ph.D. with a Fellowship from The World Bank. Two incoming students will be receiving Institute-wide fellowships: Kathleen Head, an Ida Green Fellowship and Xiaoming Zhang, a Wang Fellowship.

FACULTY

After an extensive search, Lauren Benton with a Ph.D. in history and anthropology from Johns Hopkins University, will be joining us full-time in the Fall as an Assistant Professor. Dr. Lynne Sagalyn was promoted to Associate Professor. Dr. Bishwapryia Sanyal was appointed as the Ford International Career Development Assistant Professor.

The faculty was, as usual, busy writing, conducting research, attending conferences, and performing public service. Only some of the highlights will be covered here:

Lloyd Rodwin, Ford International Professor, was elected President of the Regional Science Association and delivered the presidential address, and published his latest book, Shelter, Settlement, and Development. Donald Schon, Ford Professor, published his latest study of practice, Educating the Reflective Practitioner. Professor Bennett Harrison, with co-author Barry Bluestone, completed The Great U-Turn: Rising Inequality and Falling Wages in America (forthcoming). Professor Emeritus Lisa Peattie published Planning: Rethinking Ciudad Guyana, a reevaluation of the project she worked on 25 years ago.

Many faculty engaged in teaching, research and consulting here and abroad - including Japan, Turkey, the Philippines, Hong Kong, Italy, Saudi Arabia, Bolivia, People's Republic of China, India, Jordan, Egypt, Bangladesh, Kenya and Austria.

Adjunct Professor Mel King ran for Congress in the Eighth Congressional District. Professors Phillip Clay and Tunney Lee served on the Massachusetts Decennial Census Commission.

OTHER

Edward Linde ('62) has generously endowed a Chair to promote the study of the public role in design. His gift will help support a visiting faculty in environmental design.

The first two alumni-faculty-student forums were held on the theme of "The Changing Role of the Planner." The first topic centered on transportation and the planning for the Depressed Central Artery and featured the Massachusetts Secretary of Transportation, Frederick Salvucci ('60), Professor Ralph Gakenheimer, and Gordon Brigham (M.C.P. '63). The second was on community planning and used the ongoing planning of the Dudley Street Neighborhood Initiative as a starting point for discussion. The panelists included Professor Langley Keyes and Carla Alonso-Velez (M.C.P. '86). Each forum attracted about 75 people and generated lively discussion. Several alumni-student groups are now planning other forums for the Fall.

TUNNEY F. LEE
Aga Khan Program for Islamic Architecture

The Aga Khan Program for Islamic Architecture (AKP) established in 1979, functions jointly at MIT and Harvard University to promote research and teaching concerning architecture and urbanism in countries with Islamic societies. Generous gifts from His Highness the Aga Khan support the AKP through endowed funds that provide for faculty, student financial aid, library facilities and research; additional current funding supports publications, documentation, student travel and outreach activities.

The 1986-87 academic year was the second in the AKP’s second cycle (1985-1995); it was marked by activities both old and new aimed at consolidating, extending and broadening the work of the Program.

Mr. Yudhishthir Isar, on leave of absence from Unesco, continued as executive director. He supervised the work of a central office located at MIT whose role is to provide continuous liaison for activities carried out at both universities, to facilitate the coordination of joint, Program-wide activities, to maintain a steady exchange of fiscal and substantive information between the Program and the donor and to coordinate Program outreach in the Third world.

Faculty

AKP policy is made by an Executive Council composed of Professor Oleg Grabar, Aga Khan Professor of Islamic Art and Architecture at Harvard, Professor Ronald B. Lewcock, Aga Khan Professor of Architecture and Design for Islamic Cultures at MIT (Chairman), Professor William L. Porter, Professor of Architecture and Planning at MIT, and Professor Francois Vigier, Charles Dyer Norton Professor of Regional Planning at the Graduate School of Design, Harvard University. Other MIT faculty include Professor Yasser Tabbaa, Aga Khan Assistant Professor of Architectural History and Mr. Akhtar Badshah, Instructor/Research Associate in the "Design for Islamic Societies" unit of the S.M.Arch.S. program.

Academic Programs at MIT

Eight students were enrolled in the second year of the two year course entitled "Design for Islamic Societies" leading to the Master of Sciences in Architectural Studies degree, taught by Professor Lewcock, assisted by Mr. Badshah, and with the participation of a number of visiting critics. A further seven students joined in 1986-87, bringing the unit up to its normal strength of around fifteen to eighteen students at any one time. The unit focuses its reflection and debate on both practical and theoretical issues characteristic of non-Western societies: appropriate responses to climate, building materials and building technology; sociocultural attitudes and values which have a direct bearing on the relationship of man to his environment. The course encourages students to familiarize themselves with the architectural forms and structures found in traditional urban environments in the Islamic world and then to compare them with forms and structures which have been developed applying those Western ideas which have spread all over the world in modern times.

First year students worked on a series of three workshops. The first workshops studied the old city of Ahmedabad in Gujarat, India, examining the differences between the Muslim and Hindu neighborhoods, or Pols, and the means by which they might be rehabilitated and improved. The second workshop considered the relationship between the French colonial city of Fez -- now the center of elite life -- and the larger old walled city. The open parkland separating the two was redesigned by students so it could serve as a bridge linking the cities, and, in some cases, as a focus for the life of a new, unified city. The third workshop activity in the series was given over to the study of various attitudes to infill design.

The spring term was devoted to a studio project based on the redevelopment in Istanbul of the shoreland -- strips many kilometers long and only several hundred meters or so wide -- on both sides of the Golden Horn. Part of a larger clearance project, the strips are currently used as public parks. Solutions varied according to location, and ranged from commercial and institutional buildings to local centers and residential areas. The studio was preceded by a two week field trip where students and staff were joined by colleagues from the Building Design for Developing Countries Unit at the Bartlett School of Architecture, London University. With the assistance of Turkish architects and students, they made site surveys along the Golden Horn. The spring studio included a two-week practical building workshop devoted to traditional building materials and methods still used in Europe, Asia and Africa.

Practical work was accompanied by lecture courses and seminars emphasizing the development of design attitudes and methods that can take account of indigenous conditions, climate and appropriate building materials and theoretical approaches to creative activity in Islam.
Under the History, Theory and Criticism Program in the Department of Architecture, Professor Yasser Tabbaa and Professor Philip Khoury offered S.M.Arch.S. and Ph.D. students courses on the history of Near Eastern and Islamic architecture, and the Islamic city. Seven doctoral candidates pursued their historical study of architectural and urban form in different parts of the Muslim world. One student completed his dissertation on the rab' or apartment building in medieval Cairo and another returned from the field with an impressive array of data on eighteenth century residential quarters along the Bosphorus in Istanbul.

Student Support

Tuition and living expenses for five doctoral students and fifteen S.M.Arch.S. students were funded in whole or in part. Seventeen students at Harvard and MIT were awarded summer travel grants for study trips to China, Egypt, India, Jordan, Kenya, Lebanon, Mali, Niger, Morocco, Pakistan, the Soviet Union, and Syria.

Library and Information Resources

Specialized acquisitions and services at the Rotch Architecture Library continued to be provided through endowed funds. Under its Information Services and Technology Project, the AKP's visual documentation center completed a prototype Images System which integrates database management and graphics with videodisc technology. Some 30,000 images of Islamic buildings will be included in this innovative visual archive system. A custom designed user interface for the retrieval of images from the videodisc will allow scholars and designers to work within a personal computing environment. The completed prototype began to be tested as the year ended.

Seminars

Two AKP seminars brought together students and faculty from both MIT and Harvard as well as others interested in the topics covered. The first, held in January, 1987 during MIT's Independent Activity Period, was devoted to the topic "Western Models in Architectural Development in the Muslim World: Boon or Curse?" The discussions were based on case studies prepared by students from the Design for Islamic Societies unit; panelists included a number of MIT faculty. In April 1987 a one-day seminar on "Urban Transformations in the Fabric of Istanbul" attracted both architectural historians and students of architectural and urban design. It included presentations by scholars from Columbia University, Rensselaer Polytechnic Institute and the Ecole des Beaux Arts, as well as presentations by Design for Islamic Societies students on the Istanbul studio project.
The Center for Advanced Visual Studies, founded in 1967 by Professor Gyorgy Kepes and directed since 1974 by Professor Otto Piene, has pursued its artistic investigation of individual and group work toward integrated impulse and energies in art-science-technology. Human expression in the environmental arts and performance is its paramount concern in art works and art systems as well as in its academic, educational efforts on graduate and undergraduate levels.

Introductory classes by Otto Piene, Elizabeth Goldring, and Paul Earls, with presentations by many CAVS Fellows, address students from virtually all MIT Courses, e.g., "Art and Environment," Fall '86 and "The Artists Speak," Spring '87. In introductory drawing classes (by Nishan Bichajian) representation of the human figure and basic drawing skills and techniques were topical.

In the Master of Science in Visual Studies program, Environmental Art section, three theses were completed: "Dancing on the Horizon" by Laura Knott; "New Sound Works" by George Numrich; "Pneumatic World Theater" by Lees Ruoff-Siler. Both Ms. Knott and Mr. Numrich gave a series of performances representing their thesis work - the former in collaboration with SMVisS student Shawn Brixey. That collaborative effort led to Brixey/Knott's invitation to perform at Documenta 8, the international quintennial exhibition of contemporary art in Kassel, Germany in the summer of 1987.

While CAVS artists, graduate students, and guests created "Desert Sun/Desert Moon" in the Alabama Hills in Lone Pine, CA in June 1986 their work was filmed by a Smithsonian World crew. As a result their installations and performances became a centerpiece in "The Elephant on the Hill," a Smithsonian World TV program on art and technology aired in May 1987.

In July 1986 the Visual Arts Center of Alaska in Anchorage, AK, coproduced with CAVS "SKY ART Alaska," a series of sky events and installations in Anchorage, where Otto Piene flew his inflatable "Iowa Star."

As a result of the fourth SKY ART Conference, at CAVS in September 1986, the resident and visiting artists drafted the SKY ART Manifesto which in October 1986 was presented by Otto Piene and Lowry Burgess at the space conference of the European Academy of Arts, Science and the Humanities held at the UNESCO headquarters in Paris.

The Manifesto was also telecommunicated to the University of Sao Paulo, Brazil, and endorsed by Brazilian artists via slow-scan in a live performance event that also involved former CAVS Fellow, Charlotte Moorman at CAVS and CAVS Fellow, Joe Davis, in Sao Paulo.

A major project of the Center continues to be "Lights-OROT," an interpretation of creed with contemporary artistic media for a New York Yeshiva University Museum. The exhibition, developed by some 25 current and former CAVS artists, is scheduled to open in December 1987.

CAVS is a design consultant to Monacelli Associates, Architects, and the Cambridge Redevelopment Authority toward the creation of a major environmental, kinetic sculpture in the Cambridge Kendall Square area.

Individual artistic projects included Paul Earls' collaboration with former Fellow, Gunther Schneider-Siemssen, for First Night - a large multi-media performance on New Year's Eve on Boston City Hall Plaza, "The Creation," and Otto Piene's "Charles River Rainbow" for Harvard University's 300th anniversary. Both founding director, Gyorgy Kepes, and current director, Otto Piene, participated in several international art exhibitions (e.g., "German Art in the 20th Century," Staatsgalerie Stuttgart) and had several one-man exhibitions internationally.

Among individual grants received were a production fellowship to Elizabeth Goldring and Vin Grabill by the Diabetes Research and Education Foundation for a videotape, "The Inner Eye"; a grant by the New Works Program of the Massachusetts Council for the Arts and Humanities to Ellen Sebring and Beth Galston for an environmental performance series, "Aviary"; grants by the Massachusetts Council and the MIT Council for the Arts to Shawn Brixey and Laura Knott; a Rockefeller Foundation fellowship to CAVS Fellow, holography artist, Dieter Jung.

OTTO PIENE
The Center for Real Estate Development (CRED) has completed its third full year of operation. On October 18, 1986, MIT awarded 34 degrees to the second class to receive the Institute's new degree of Master of Science in Real Estate Development. Two additional joint degree candidates in this class received their degree at the June 1987 commencement. The Center's fourth class of masters degree candidates will enter this fall.

This year attention has been focused on improving our educational program, and broadening our corporate membership and fundraising activities. Under the guidance of Michael Wheeler, the new director of education; Gloria Schuck, lecturer in the Sloan School of Management; and Sandra Lambert, the Center's new research associate, the Center developed and refined new curriculum materials. Production of case studies in the fields of real estate investment, development, and management are well underway.

The education program continues its close association with the departments of architecture, urban studies and planning, civil engineering, economics, and the Sloan School. Participation in classes by a broad spectrum of MIT and Harvard students has increased. A sustained high ratio of applicants to admitted students in our masters degree program is evidence of the continuing success of the graduate program and its core courses. Another measure of success is the excellent employment opportunities that our graduates enjoy in a wide range of fields relating to development.

The Center's founding and new member companies provide a steady financial base for the programs. Seven new member companies ranging from the real estate departments of investment banking firms to architectural firms have joined the Center.

Two members meetings were held during the past year. The theme of the December 1986 meeting was "Foreign Investment in U.S. Real Estate," with speakers from the Japanese government as well as from Japanese and European development firms. The June 1987 meeting explored "Emerging Opportunities in the Market." Speakers included a demographer, an economist, and practitioners in the field.

Two significant research projects were completed and published this winter. David Birch's two-year study of "America's Office Markets 1985-1995" (the first nationwide office space forecast based on job growth projections), was co-sponsored by Arthur Andersen and Co. and has been translated into Japanese. Russell Lindner's and Edward Monahan's work on "Japanese Investment in U.S. Real Estate" was also published. Over 1,000 requests, both from the private sector and from universities, have been received for their report. In addition, working papers have been produced from the Affordable Housing Research program, dealing with financing, consensus building, and design issues. Other research papers analyzed office market cycles, the resolution of development disputes, and the history of height restrictions in Boston.

Summer 1987 professional development course offerings included new courses: Presentation Skills for Developers, and Real Asset Management, as well as proven courses: Marketing, and Negotiations.

Other educational programs are being planned, including the Center's pilot executive education program for real estate developers. The goal of the intensive course will be to refine the strategic planning skills of leaders in the industry.

In response to a request from the Minority Developers Association of Boston, the Center is developing a short, intensive educational program designed to help principals and key managers of minority development firms pursue commercial and office development opportunities more competitively.

Professor Lawrence Bacow has returned from sabbatical to assume the directorship of the Center's research activities.

Confident that our educational program is firmly established, the Center will focus during the next year on new research initiatives, while continuing to widen its base of financial support for research and education.
Research projects based in the Laboratory of Architecture and Planning (LAP) are directed by LAP faculty and research staff, and often involve outside professionals and organizations as well as students. Funding for the LAP's broad range of projects comes from government on the national, state, and local levels; from foundations, industry, and individuals. The international relevance of the work conducted through the LAP is indicated by the support of international agencies as well as industry and foundations outside the US.

Many activities of the School of Architecture and Planning are organized as special interest programs; the LAP serves as the administrative base for all of the sponsored research and many of the educational workshops conducted within these programs. Among these programs are: The Center for Real Estate Development (CRED), the Professional Practice Program for Housing and Human Settlements, the East Asian Architecture and Planning Program (EAP), the Aga Khan Program for Islamic Architecture (AKP), the Special Program for Urban and Regional Studies (SPURS), the Computer Resource Laboratory (CRL), and the Program for Neighborhood and Regional Change.

In addition, the LAP has strong connections with other centers of research at MIT. The LAP actively collaborates with colleagues in the Sloan School of Management, the MIT Joint Program for Energy Efficient Buildings and Systems, the Media Laboratory, and the Center for Construction Research and Education, among others. The LAP is also involved in research and special educational efforts on a collaborative basis with institutions in East Asia, the Middle East and Latin America.

MAJOR DEVELOPMENT EFFORTS

The LAP continues to host a range of basic and applied research projects. Two of this year's projects drew national attention. First, Associate Dean Lois Craig and Research Associate Mary Jane Daly directed the Massachusetts Governor's Design Awards Program. The citizen participation process of the Awards Program emerged as an exemplary model for other states. The LAP's involvement with the Governor's Design Awards Program continues a tradition in the School of Architecture and Planning of examining and developing citizen participation models of lasting value to public and private development efforts. Second, "America's Future Office Needs", a research report completed by Senior Research Scientist David Birch for the MIT Center for Real Estate Development, received national and international acclaim. Dr. Birch continues to receive international recognition for his research on job generation in the US and Europe. This year, his research has been featured in major business magazines including Forbes and Fortune. He is now a regular columnist for INC magazine.

The LAP continued to press ahead on the development agenda set forth by the School Council. Two areas saw significant progress.

The building technology research program received a major boost with the appointment of Professor Leon Glicksman, Director of the MIT Program for Energy Efficient Buildings and Systems, to a senior tenured position in the Department of Architecture effective July 1. Long-term research programs have now been mounted in three focused areas: real property portfolio management, housing systems and composite materials, and thermal materials. An agenda for building technology research in developing countries was also drafted and is now under review. Other research work relates to R&D management, and computer aided design and expert systems. An international research symposium about state-of-the-art research relating to CAD was jointly sponsored by the LAP and the School's Computer Resource Laboratory. A symposium about Real Property Management was held in January 1987, sponsored by the MIT-Shimizu Construction Company Research Program which provides a window into MIT for research. Projects under this umbrella program are now focused on information concerning real property management, materials, design, and construction techniques.

A second area for major development by the LAP has been the School's East Asian Architecture and Planning Program (EAP). The program-sponsored seminars included design studios in China and Japan. The EAP has also emerged as a significant generator of research relating to a number of topical areas, including real estate development and construction technology. The EAP has begun negotiations to formalize collaborative educational and research relationships with the University of Tokyo, the University of Hong Kong, Tokio Institute of Technology, and Tsinghua University in China. This year the EAP launched an endowment to underpin the program in the memory of one of the Program's founders, Paul Sun (M.Arch '59), in whose name the Program also initiated an annual lecture series.
CURRENT RESEARCH

James McKellar continues to be the Principal Investigator for projects carried out under the cooperative agreement between CRED and the North Atlantic Region National Parks Service. Work done under the agreement aims to assess the potential involvement of the private sector in managing park properties.

Lois Craig and Mary Jane Daly serve as co-Principal Investigators for the Governor's Design Awards Program, a new awards program sponsored by the Massachusetts Council for the Arts and Humanities. This innovative program seeks "to recognize and encourage improved design" in the state of Massachusetts, and brings together a variety of artists and designers from around the state.

Lois Craig serves as principal investigator of a National Endowment of the Arts supported program to develop a visual collection describing the Boston suburbs.

LAP Director Michael Joroff and Professor Eleanor Westney (Sloan School of Management) completed their field work on the research and development process in the Japanese construction industry. This research effort is funded by the National Science Foundation, and forms the spine of a body of comparative research into the Japanese construction industry being conducted by faculty and researchers in the School. Additional support for these research efforts is being provided by the Mori Foundation, the Shimizu Construction Company, the Grunsfeld Research Incentive Program, and other private sponsors.

Professor Ranko Bon (Department of Architecture) and Michael Joroff are co-Principal Investigators for a project to develop a theory and basic methodologies for building portfolio management. This research focuses on how private companies and institutions comprehensively manage large numbers of property and buildings. Current work is funded by the Shimizu Construction Company.

Professor Eric Dluhosch continued work on a computer-based educational package designed for the International Masonry Institute. The resulting product, "Masonry Computer", combines an existing data base with a videodisc component and drawing module that provides a tool for designing with masonry. The product has met with success and further development of the package will continue next year.

Professor Donald Schon (Department of Urban Studies and Planning) and Professor Lawrence Bucciarelli (School of Engineering) continued as co-Principal Investigators for a grant from the National Science Foundation to support their project, "Generic Design Processes in Architecture and Engineering". This project will explore the processes and tools of design to build an understanding of its generic and domain specific features. Descriptions of these features will inform the development of better tools for designing, especially those which are computer-based.

Professor John Habraken (Department of Architecture) also completed work on a grant from the National Science Foundation. "Design Games as Means for Experimentation in Design Theory and Methodology" is a project in which the initial premise is that design is game-like activity; with this established, the research will use games to test design theories and develop new operations.

Professor Nabeel Hamdi (Department of Architecture) and Research Associate Reinhard Goethert (Department of Architecture) continue their work for the Ministry of Housing in Sri Lanka, concentrating on housing and construction policy and strategy.

Principal Research Associate John Klensin (LAP) continued his work with the Infoods project, an ongoing effort to develop facilities for an international exchange of data on the nutrient composition of foods. The project is funded by the National Institute of Health.

Professor Patrick Purcell (Department of Architecture) and Professor Robert Logcher (Department of Civil Engineering) completed their project on "Knowledge-Based System Development for Facilities Planning". They developed and evaluated IBM's expert system building tool known as PRISM as a knowledge-based system for facilities planning. The project was funded by IBM Corporation.

Professor Bernard Frieden (Department of Urban Studies and Planning) and Michael Joroff are co-Principal Investigators for a US-Japan comparative study of public and private interaction in real estate development. The project is funded by the Mori Building Company.

The Grunsfeld Research Incentive Awards continue to provide a very important source of funding for small-scale exploratory research by students and faculty of the Department of Architecture.

The LAP continues as one of the sponsors of Open House International, an international journal of housing, co-edited by Professor Hamdi of MIT's Department of Architecture.

Professor Mark Schuster (Department of Urban Studies and Planning) is developing an "Urban Form Primer" to help development decisions concerning rapid growth in small towns located in metropolitan areas. The primer will be used by town administration and developers when negotiating about the form of new development. The project is funded by the National Endowment for the Arts.
Senior Research Scientist David Birch (LAP) continued his work with "Future Job Opportunities in Nebraska." This project offers a study of employment factors and opportunities for Nebraska's future. The project was funded by the Department of Labor in Lincoln, Nebraska.

Dr. Birch completed his study of America's Office needs, a comprehensive analysis based on his model of job generation. Dr. Birch's data base about job generation is the largest in the US. The research was funded by Arthur Anderson, Inc. and the MIT Center for Real Estate Development.

Professors Leon Glicksman and Shahryar Motakef (Department of Mechanical Engineering) completed their project on "Moisture Transfer in Horizontal Roof Insulation Systems." This research involved development of a resistance type moisture probe and the study of its calibration characteristics to help understand the principles governing moisture transfer and to help predict moisture distribution under various environmental conditions. This project is designed as timely support to the Oak Ridge facility which is doing large scale experimentation. This subcontract project was funded by Martin Marietta Energy Systems, Inc.

Professor Glicksman also completed his project on "Joint Program for Energy Efficient Buildings and Systems." This research included an integrated approach to air circulation in the interior and exterior of a building, heat and moisture transfer through exterior walls, and measurement and control of a building energy system. The project was funded by the Department of Energy/San Francisco.

Deborah Hoover continues her research on cultural policy in The Gambia. This project is funded through private individuals and foundations as well as support from the Dean's Office and Dr. Jerome Wiesner's office at MIT.

Research consultant George Clark and Professor Glicksman continue to supervise the development of the lighting research and education laboratory. This development is supported by GTE Sylvania.

Professor Karen Polenske (Department of Urban Studies and Planning), with support from the National Council on Public Works Improvement is conducting three studies about infrastructure development. One study reviews infrastructure investment in other industrialized nations. The focus of the review is on two issues: the relationship between infrastructure investment, economic development, and economic competitiveness; and the decision-making process for public-works expenditures. A second research project cross tabulates the key infrastructure financing tools by level of government offering the finance, kind of infrastructure expenditure for which it is used and purpose of infrastructure expenditure. The third study analyzes the current status of infrastructure provision at the state level in the United States. The research focuses on three questions: What are the major issues facing public infrastructure planners at the state level? What are the current procedures and processes for state infrastructure planning? What alternative strategies exist for state infrastructure planning?

STAFF

Michael Joroff was a member of the organizing committee of the Second International Office Environment Conference, which was held in Gotemba and Tokyo, Japan. Professor John Habraken was a distinguished guest of Tokyo University, under the auspices of the MIT-East Asian Architecture and Planning Program. Professor Eric Dluhosch served on the International Competition Committee of the National Institute of Building Sciences.

The LAP hosted several long-term international visitors this year, including Professor Takashi Koshizuka from the University of Tsukuba, Japan; Professor Chang-bok Yim, from SangKyum Kwan University, Korea; Dr. Fumio Hasagawa, from the Shimizu Construction Company, Japan; and Professor Koji Yagi of the Tokyo Institute of Technology.

Ms. Bonny Hafner joined the LAP as Administrative Assistant. Dr. John Klensin, associated with the LAP since its inception in 1973, transferred to the Center for International Studies. Research Associate Mary Dolden left the LAP to begin a private design firm and Mary Jane Daly left the LAP to become a senior staff member of a design and planning firm. John Crowley, former research director of Ryan Homes, joined the LAP on a part-time basis to lead the development of a housing technology program.

MICHAEL L. JOROFF
The Media Laboratory continues to grow at almost 50 percent per year, achieving a sponsored research program of $3.8M this fiscal year. Not included in this figure are $700K of fund monies provided as discretionary funds by companies, foundations, and philanthropists.

The number of corporate research sponsors, including industrial consortium members, has grown to 30. In all, the Laboratory maintains the highest percentage of corporate (versus government) funding of any MIT interdisciplinary laboratory.

The year has included major hardware gifts from Apple Computer, Inc.; Sony Corporation; and Hewlett Packard Company. Gould Inc. has provided the largest single hardware gift this year, by furnishing a VAX compatible PowerNode 9080 computer system, accompanied with an advanced IP8400 graphic system, valued at $750K. The Gould equipment is being used in a recently completed computer facility in the basement of the Wiesner Building. The application is advanced computer graphics and animation for education, medicine, and entertainment.

The year closes with a signed major endowment agreement at the Media Laboratory — the Nichidai Fund. A group of Japanese industrialists, mostly graduates from Nihon University in Tokyo, Japan, have provided $10M to the Media Laboratory, to be paid over two years, the first payment of which has been received. Interest from the funds will be used to support ongoing Media Laboratory activities and to help Nihon University build a laboratory similar to that of the Media Laboratory at the International Advanced Research and Development Institute (IARDI) in Japan. After five years, $10M will remain for pure endowment of the Media Laboratory.

Earlier this year, the Fukutake Publishing Company endowed a career development chair in the Epistemology and Learning Group, which has been awarded to a new faculty member, Dr. Edith Ackermann.

The Laboratory continues to attract a disproportionate number of visitors. Over 1000 groups have been hosted this year. The distraction of such visibility is likely to increase in the coming year with the August 7, 1987 release of a book called: The Media Lab: Inventing the Future at MIT, written by author Stewart Brand and published by Viking Penguin Incorporated.

RESEARCH ACTIVITIES

The Laboratory is presently composed of 12 groups:

- Advanced Television Research Program
- Computer Graphics and Animation Group
- Electronic Publishing Group
- Epistemology and Learning Group
- Film/Video Group
- Human Interface Group
- Movies of the Future
- Music and Cognition Group
- Spatial Imaging Group
- Speech Research Group
- Visible Language Workshop
- Vision Science Group

Media Laboratory Sponsors

ABC, Ampex, HBO, Kodak, NBC, PBS, RCA, Tektronix, Zenith
AERG, General Motors, Hughes, MSF, USWest, IBM, NYNEX
Apple, ICL, NHK, NSF
Apple, Lego, MacArthur, NSF, Apple, Ann & Gordon Getty Foundation, MCAH, NEA, NSF, SDF

Columbia, Paramount, Warner Bros.
NSF, DARPA, NTT
Heli Graphics, IBM

Arbitron, DARPA, NSF, Polaroid,
ADVANCED TELEVISION RESEARCH PROGRAM

This is a program whose activities are split between the Research Laboratory for Electronics and the Media Laboratory. It is a consortium of nine companies (American Broadcasting Company; Ampex Corporation; Eastman Kodak Company; National Broadcasting Company; Public Broadcasting Service; RCA Corporation; Tektronix, Inc.; Time Inc.; and Zenith Electronics Corporation). The group includes two newcomers to the program (Eastman Kodak Company and Zenith Electronics Corporation).

Work continued on this Program, under the leadership of Professor William F. Schreiber. The Program, which has as its main goal the development of the scientific and technological bases for the improvement of picture and sound quality in present and future television systems. During this period, a computer-based simulation system for moving images was placed in service. With this system, methods were demonstrated for improved conversion from one frame rate to another and for motion-compensated noise reduction. Progress was made in the deblurring of images degraded by camera integration. A system was conceived and computer-simulated for improving the efficiency of television transmission systems using frequency modulation, as in satellite transmission and video tape recording. A series of audience tests was carried out in a suburban shopping center to assess the reaction of ordinary viewers to several aspects of image and sound quality.

COMPUTER GRAPHICS AND ANIMATION GROUP

Assistant Professor David Zeltzer directs this group which is funded by NHK and ICL of Japan and Apple Computer, Inc. of the US. Their task is the design and implementation of an intelligent animation system which will allow non-expert users to define and control the behavior of realistic, articulated figures in complex, simulated environments. Professor Zeltzer was awarded in June a major, three year NSF grant for “Modeling Motor Behavior and Virtual Environments for Three-Dimensional Computer Animation.” The past year saw continued development of motion control systems based on inverse kinematics and the simulation of Newtonian mechanics. Work has also begun on a graphical interface incorporating constraints, as well as the implementation of behavior control for animated, autonomous agents based on a method called “motor problem solving.”

The uniqueness of the group comes from its emphasis on the intelligence and physics embedded in their systems. Other computer animation groups around the world limit their primary focus to that of image making and rendering, versus knowledge representation.

ELECTRONIC PUBLISHING GROUP

Continuing under the leadership of Principal Research Scientist Walter Bender, this group remains the national leader in investigations in the use of greyscale techniques for display quality. The group has embarked on a program of color coding that deploys semantic information processing in order to reduce the data storage requirements of photo-realistic, computer displays. We believe this program to be utterly unique.

The focus was on “looking at the image.” An examination of both temporal and spatial frequency has been used to bias the statistical analysis colors found in full color images. They have been trying to identify parts of the image of interest to the observer. In addition to improving their color compression algorithms, they have developed techniques for making high resolution video stills by trading temporal resolution for spatial resolution.

Application of these techniques is embodied in personalized information systems. A consequence of the synthesis of media through active processing is the merger of newspapers and television. The result is a newspaper with illustrations which move or, conversely, print as television output. The latter is the theme of Network Plus, an experiment in combining news wire services with network television news. The goal is to provide both an annotated, real time newscast composed at the time of viewing, and to provide the data base for composing an illustrated personal newspaper printed immediately after the telecast. Wire service stories are used to annotate the network news, by examining the closed captioning accompanying the broadcast. Ancillary contextual information is gleaned from processing the broadcast. A rough determination of speaker emphasis can be correlating pitch and intonation of the audio signal with the transcripts. Scene analysis is used to find relevant still images. The editorial direction is dictated by the broadcaster, while the content is enriched from a variety of sources.

EPISTEMOLOGY AND LEARNING GROUP

The Epistemology and Learning Group started the year with a major setback in funding which put into jeopardy the Hennigan School program, which includes 210 children from grades one to five. The Hennigan School is the site of experimentation with advanced concepts for high design computing in the total educational experience of children, in this case in an inner city, public school system.
The year closed with a major rebound of sponsorship from new funding sources, most notably Apple Computer, Inc., the National Science Foundation, and the MacArthur Foundation. Lego continued its funding.

FILM/VIDEO GROUP

The Film/Video Group is under the direction of Professor Richard Leacock. The year has included two major projects: an experimental workstation and a performance called Radio Interference. A collaboration with The Antenna Theater Group in producing Radio Interference in the Experimental Media Facility allowed the Film/Video Group to gain experience in a new area and to demonstrate to funding agencies that they are part of a laboratory that is well suited to carry on much more complex research in a potentially rewarding field. Of the 13 pieces in Radio Interference, four and one-half were conceived and created by Film/Video, and the others largely depended on Film/Video’s contributions. The performance moved to San Francisco where they had to extend the run, and it seems likely at this point that it will be invited to Brooklyn Academy of Music (BAM) in New York and perhaps to a Kennedy Center celebration of avant garde theater next year.

HUMAN INTERFACE GROUP

This group was awarded a major two-year grant by the National Science Foundation commencing November 1, 1986 to study “Eyes in Multi-Modal Human/Computer Dialogue.” The research will explore and evaluate eye movements in human/computer dialogue, both alone and in combination with speech and manual pointing. The emphasis will be on looking at behavior as evidence of interest and attention, and as a means of reference.

Dr. Richard A. Bolt, head of the Human Interface Group, was invited to contribute an article on “Integrated Multi-Modal Displays” to the special November 1987 issue on the Human Interface of TRANSACTIONS OF THE IECE (Institute of Electronics and Communication Engineers of Japan), one of Japan’s largest and most prestigious technical societies.

Dr. Bolt also presented a day-long tutorial at the April 1987 meeting of the CHI + GI Conference on Human Factors in Computing Systems and Graphic Interface held in Toronto, Canada. The subject of the tutorial was “New Directions in Multi-Modal Interface Design.”

MOVIES OF THE FUTURE

This program is a new consortium funded by Paramount Pictures Corporation; Columbia Pictures Industries, Inc.; and Warner Brothers, Inc., under the direction of the Media Laboratory’s Associate Director, Andrew Lippman. This work was featured in September at MIT’s national Alumni Symposium in Los Angeles.

Research highlights include a program to store a complete feature film, digitally coded, on a compact audio disc. This is an example of “asymmetric coding” in that the encoding process can be complex and processor intensive, but the decoder must be real time, efficient, and inexpensive. By virtue of the off-line encoding, it is reasonable to take new approaches to image sequence coding including global, or look-ahead techniques, where the channel capacity is allocated to images within sequences and between sequences based on high level human perceptual features. In addition, algorithms can be modified to suit differing content. As of this writing, a variation of three-dimensional vector quantization is being used as the basis, and the current image quality is slightly below that of consumer videotape. New algorithms for code table generation are the main thrust of the current work.

Other work in this area involves three-dimensional scene coding, where an estimate of the 3-D world, from which a set of images is derived, form the basis for predicting future frames. This work has been done using the multiple processor architecture of the Connection Machine and has been merged with work on a new camera that captures three dimensional data. A result of this is the synthesis of new images seemingly taken from a different perspective from that of the actual camera.

MUSIC AND COGNITION GROUP

The Music and Cognition Group is the joint effort of Professors Marvin Minsky and Barry Vercoe, and Assistant Professor Tod Machover. In each case, music is the object of a different intellectual inquiry. For Professor Minsky, music is the object of epistemological research, extensions of which are found in the implementation of his recent book, Society of Mind.

In Professor Vercoe’s case, music includes advanced signal processing for both room acoustics research and the development of a synthetic performer. The latter entails computer tracking of music for human-like accompaniment.

Assistant Professor Machover, meanwhile, works on the generative side of sound, with his research in hyper-instruments. His own work includes the opening opera commissioned for IRCAM’s 10th anniversary, at the Centre Georges Pompodou in Paris this fall.
SPATIAL IMAGING GROUP

The Spatial Imaging Group continues under the direction of Professor Stephen Benton, with primary sponsorship coming from General Motors Corporation and Hughes Aircraft Company. The Defense Advanced Research Projects Agency (DARPA) funding was discontinued in January, but new funds have recently been provided by US WEST Advanced Technologies. This year included the achievement of a projected synthetic hologram, all the data of which came from a GM computer aided design system. The 180 degree "walk around" display is unto itself a spectacle. Further research includes full-color imaging. Other applications have included medical imaging, using data provided to them by Harvard University. A new research contract is just beginning, with the goal of transmitting holographic images over future telephone lines. The long term goal of the group continues to be real time synthetic holography.

SPEECH RESEARCH GROUP

The Speech Research Group, headed by Principal Research Scientist Christopher Schmandt, has been working on non-phonemic cues to speech understanding. Rather than try to identify what words someone is saying, the goal is to understand their intention based on "tone of voice" and speech style. Similarly, the group is working on synthesizing intonation so computers can be more lively participants in conversations. This research is being applied to the task of understanding human responses while the computer is reciting a series of driving directions, to try to understand whether the human understands the directions, needs more information, or just wants the computer to slow down.

VISIBLE LANGUAGE WORKSHOP

Graphics research in the design, photo-graphics, and typo-graphics context continues in the Laboratory's Visible Language Workshop, under the direction of Associate Professor Muriel Cooper. The year has included a major strengthening of that group's hardware and human resources. One result is a major proposal (still outstanding) to DARPA for advanced typographies in debugging.

VISION SCIENCE GROUP

The Vision Science Group is a new group, founded during this academic year. It comes into existence with two new faculty members, Dr. Alex Pentland and Dr. Edward Adelson. A new vision laboratory is currently under construction and equipment is being purchased. Research will cover basic problems in human visual perception, machine vision, and image modeling. The results will be applied to visual display systems, image analysis, and image understanding.

OTHER RESEARCH in the Media Laboratory falls between groups or leads into new directions. An example of the latter is work being conducted by Associate Director Andrew Lippman which addresses simulation techniques for endoscopic surgery. This is a small program funded by a new group, the Medical Simulation Foundation. Involved in the program is the interfacing of a medical arthroscope to a graphics system so that the position and orientation of the instrument are known to the computer within four degrees of freedom. This information is then used to merge the video output of the arthroscope with the three-dimensional data base of the anatomy stored in the computer. The surgeon thus gains a true perspective in the operating theatre. In the long run, this type of joint visual and computational imagery can project non-invasive, endoscopic surgery into a new generation of technique with new instruments and processes.

PERSONNEL

Through this year, the Media Laboratory and the Media Arts and Sciences Degree programs were more or less one and the same, headed by Professor Nicholas Negroponte. 72 percent of the 52 graduate students in the degree program were full-time research assistants in the Laboratory. Nine students from other departments were full-time research assistants in the Laboratory as well. The Laboratory behaved as both an interdisciplinary research center and as a quasi-academic department.

In the fall of 1986, Professor Stephen Benton was granted tenure. A few months later he was promoted to full Professor. It was decided that as of July 1, 1987 he would be in charge of managing all academic affairs, effectively decoupling the research management from the curriculum development. This is an important change which is expected to result in a marked improvement of our teaching.

Effective for the same time, Andrew Lippman was appointed Associate Director of the Laboratory in response to our rapid growth in all areas and our continued need to fund-raise for endowment.
New faculty who joined the Laboratory and academic program include: Assistant Professor Edith Ackermann and Associate Professors Alex Pentland and Edward Adelson (who has a joint appointment with the Department of Brain and Cognitive Sciences). The addition of these three junior faculty has greatly strengthened the scientific substance of our program.

Other staff changes have included the addition of Stuart Cody and Gregory Tucker as Technical Instructors and Stephen Ocko as a Research Associate.

NICHOLAS NEGROPONTE
School-wide efforts receiving special emphasis this year have included: intensive continuing efforts to realize the School's Goals for Engineering Education, in the context of the Institute's overall reexamination and restructuring of its undergraduate program, and continued development of a major program in Manufacturing.

Undergraduate enrollment in the School has followed the trend of the last year or two, with a slightly decreased total, to 2225 as compared to last year's 2303, and a continued shift from Electrical Engineering and Computer Science to primarily Aeronautics and Astronautics, which increased by 33 to 334. Mechanical Engineering, after a long period of increase, has in the last year decreased slightly, and other departments are relatively stable in enrollment.

UNDERGRADUATE EDUCATION

The Commission on Engineering Undergraduate Education, led by Dean Jack Kerrebrock, has pursued a number of initiatives to further the School's development of its undergraduate programs. A major effort in collaboration with the School of Humanities, Arts and Social Sciences led to the adoption at the end of the Spring semester of revised requirements for the Distribution in Humanities, Arts and Social Sciences, as well as the creation of a Minor in HASS, available to all undergraduates at the Institute. The Minor in HASS will allow students in Engineering and Science to Minor in any of several areas of humanities, arts or social sciences, by taking one additional subject in HASS, beyond the Institute requirement, as part of a coherent set of six subjects.

An Interschool Working Group on Contexts Subjects, chaired by Professor Elias P. Gyftopoulos, is sponsoring the development of a number of such subjects, some for introduction as early as the Spring semester of 1988. Each subject will be conducted cooperatively by faculty of two or more schools, and will bring forth the differing viewpoints which persons of various backgrounds bring to a common subject. Some of the subjects which will be offered are: "Negotiations in Engineering Systems"; "Engineers, Scientists and Public Controversy"; "The Decision to Build the H-Bomb"; "The Effects of Labor-Saving Technology on the Engineering Work Force"; and "Japanese-US Competitiveness".

A Faculty Instructional Resource Program has been established in the School with Associate Professor Edward F. Crawley as Chairman. Its purposes are: to visibly signal the School's commitment to teaching by making available to the faculty the theoretical background, practical demonstrations, and feedback mechanisms to enhance teaching skills; to orient the faculty to the educational resources of MIT, their interrelationship and organization; and to develop an interdepartmental network among faculty for teaching. It will proceed by developing practical and useful teaching resource material, by conducting teaching workshops for faculty, and by developing a tutor/mentor program to provide feedback and coaching to young faculty.

The Working Group on Teaching of Design chaired by Associate Professor Woodie Flowers, is addressing the means by which MIT can provide an environment more conducive to the teaching of design and to developing the students' innate design talents.

Plans are being made for collaboration between the Undergraduate Research Opportunities Program and the Industrial Liaison Program, to expedite the support of undergraduate research by member firms of the ILP. In the course of their normal interactions with industrial representatives, ILP personnel will identify opportunities for such support, which will be made known to faculty and students by the UROP. It is hoped that this will both provide needed financial support for undergraduate research and enhance faculty-student-industry interaction.

To help improve teaching quality and to more carefully monitor the demand placed on students in the School of Engineering, last fall the CEUE initiated a collaborative effort with the Undergraduate Association Course Evaluation Guide General Committee (CEG) to expand the number of subjects and instructors evaluated in the School. The CEUE first examined how subject reviews in each Engineering Department had been conducted in the past. Its findings are contained in the July 1986 CEUE report, Subject Evaluations in the School of Engineering. To facilitate the expanded effort, the CEUE helped establish a new administrative process in each Engineering Department, worked with the CEG students to revise their Engineering subject evaluation forms, and provided financial support to the CEG. As usual, the CEG students conducted the actual evaluations and analyzed the results. As a result of these joint efforts, 50 percent of Engineering subjects were evaluated in the Fall 1986 term, and 70 percent in the Spring 1987 term. Next fall, the CEG hopes to evaluate all Engineering School subjects. The results are to be reviewed in summary form each semester by Engineering Council, with particular attention to the student workload imposed by the individual subjects, and to the quality of teaching in each subject.

In April 1986, Ms. Robin M. Wagner '86 joined the staff of the School of Engineering in a half-time position as the Special Assistant to the CEUE. Her role has been to facilitate communication between the School of Engineering faculty and the student body on matters of concern to the CEUE, to study engineering students' views on their MIT education and present the findings to the MIT community, and to conduct research and serve as Secretary for the CEUE and several of its Subcommittees.
Over the past year, Ms. Wagner has undertaken a number of projects for the CEUE, in collaboration with other staff members from the Office of the Dean of Engineering and other MIT offices. A total of eighteen students have been hired by the CEUE, and, in some cases, the Undergraduate Opportunities Research Program (UROP) to assist in the research, analysis and oral and written presentation of the results of projects, which included: a student survey on engineering undergraduate education, research on freshman residence/orientation (R/O) week, a project on student/faculty relations, living group-based student study groups on MIT educational policy, and an undergraduate education bulletin board in The Tech.

An Independent Activities Period (IAP) subject "Seeing the Big Picture: Ethical Choices in the Practice of Science and Engineering" was conducted, which was taught by faculty from several departments and schools and brought to MIT a number of guest speakers. The discussion by Roger Boisjoly, formerly of Morton Thiokol, of events preceding the Challenger accident, has attracted considerable attention. A videotape of his talk has been distributed to other universities for use in subjects on ethics.

MANUFACTURING

Leaders for Manufacturing has the objective of focusing a significant fraction of MIT's engineering faculty and graduate research effort on the fundamental issues of manufacturing productivity, with substantial collaboration from the Sloan School of Management. It envisions groups of faculty and students studying manufacturing processes and organization in the industrial environment, to adduce the critical issues for extended study at MIT. It will also bring leaders in manufacturing to the MIT campus, for seminars and cooperative research.

Dean Gerald L. Wilson and Professor H. Kent Bowen have developed the conceptual basis for Leaders for Manufacturing through extensive conversations with representatives of a number of companies, including automobile manufacturers, electronic and computer companies, an aircraft company and an oil company. There has been general acceptance of the proposition that an intensive cooperative program between academe and industry will be helpful in improving the competitiveness of US industry.

ENGINEERING INTERNSHIP PROGRAM

For the summer of 1987, 53 sophomores were placed in the Engineering Internship Program (E.I.P.). The total enrollment is now 126 students with 33 companies actively participating in the Program. Beginning at the end of the sophomore year, the E.I.P. provides work experience at a participating company during two undergraduate summers and one graduate summer and academic term. The Program leads to the simultaneous awards of the S.B. and S.M. degrees with the S.M. thesis done at the company during the graduate work experience. Four new companies chose to participate for 1987. The Boeing Company, Seattle, Washington; Jet Propulsion Laboratory, Pasadena, California; the MITRE Corporation, Bedford, Massachusetts; and Schlumberger Technology Corporation, Houston, Texas.

AFFIRMATIVE ACTION

The School continued its policy of offering positions to outstanding women and minority candidates. A key element of this policy is to seek minority and women faculty irrespective of the specific fields authorized for faculty searches. For the third year the policy also included funding of postdoctoral positions for women or minority candidates with good potential to become faculty members. During 1986-87 faculty positions were offered to five women, four of whom accepted, bringing the number of women faculty in the School to fifteen. The resignation of Professor Wesley Harris, who left MIT to assume the position of Dean of Engineering at the University of Connecticut, brought the number of black faculty to four. Department Heads, schoolwide, have undertaken new initiatives aimed at recruiting minority faculty members.

MINORITY INTRODUCTION TO ENGINEERING AND SCIENCE

In the summer of 1986, forty high school juniors attended the MITES program. A six-week summer program for minority students emphasizing their academic development in engineering and science, MITES began in 1975 as part of a program developed by the Engineers' Council for Professional Development. It had been directed at MIT since its inception by Professor Ernest Cravahlo, until 1987, when Professor Raphael Bras became Director.

The MITES curriculum covers academic disciplines including mathematics, physics, humanities, design and computer science. It is a rigorous program and is structured so that students can utilize the campus-wide computer system in the completion of their assignments. One of the special features of the program is the exposure in the classroom to distinguished faculty. Outside of the classroom, there are a number of scheduled activities including tours and orientation programs, career-related guest speakers, field trips, and social events.

Admission to the MITES Program is highly selective. It is open to high school juniors and is based upon PSAT scores, grades and recommendations. Between 200 and 300 students apply annually, of which 40 are selected.

Most MITES alumni enter undergraduate programs in engineering and science at institutions such as MIT. Of the 40 students who attended the program in 1986, 38 sought admission to MIT; all but two of those were offered admission. Nineteen of those offered admission have indicated that they intend to enroll in the fall of 1988.
SECOND SUMMER PROGRAM

Under the direction of Professor Leon Trilling, the Second Summer Program will enter its ninth year of operation in the summer of 1987 with 33 students and eight companies participating. The Program, which started in 1979 with ten students, provides an intensive summer educational and work experience to any interested MIT minority engineering students following their freshman year.

JACK L. KERREBROCK
GERALD L. WILSON
Compared with last year, the number of personnel changes is quite small, and we welcome this relative stability. Professor Amadeo Odoni returned from a Sabbatical leave and was invited to be the Co-Director of the Operations Research Center. After some deliberations, he accepted this challenge on a part-time basis. We are pleased by this recognition of his abilities, which were not a very well-kept secret, but miss his wisdom in departmental deliberations. We also miss Associate Professor Bruce K. Walker, who resigned to accept a new position at the University of Cincinnati.

On the positive side, we have welcomed Professor Sheila E. Widnall back from her Sabbatical leave. A goodly part of that leave was spent carrying out those activities associated with the office of the presidency of the American Association for the Advancement of Science.

We are pleased to note that Associate Professor Edward F. Crawley was awarded tenure effective July 1, 1987. Assistant Professor R. John Hansman was promoted to Associate Professor, also effective July 1, 1987.

Dr. Belgacem Jery, whose research is associated with dynamically coupled loads in rotating machinery, has accepted our offer to join our faculty. As the demands for increased specific thrust of gas turbine engines becomes more insistent, problems of shaft and seal dynamics will become more important. Dr. Jery has been assigned to the Propulsion Teaching Division.

Mr. Jeffrey C. Di Tullio has accepted our offer to join us as a Technical Instructor. As the number of students in our laboratory classes becomes larger, he will be increasingly valuable to the Department.

As of July 1, 1987, the Department faculty consisted of 22 full professors (not counting Dean Kerrebrock, Professor Ezekiel, the Director of the Center for Advanced Engineering Study, and myself), six associate professors and nine assistant professors. This puts us at about the complement contained in the Dean's manning table.

In the two previous reports, we had discussed the Department's current man-powered airplane project. The goal of this project is to build an airplane capable of man-powered flight from Crete to mainland Greece. Over the previous summer, a prototype airplane was built, and preliminary testing was conducted at Hanscom Field, in Bedford. The results of these tests indicated the airplane had considerable potential as a long-range man-powered airplane. In January, Professors Bussolari and Drela accompanied the airplane to Edwards Air Force Base for further flight testing. One of the outcomes of that test period were two new world records. Glen Tremmel, of Yale, set a new record by flying the airplane 37.3 miles. Lois McCallin, a visiting engineer in this Department, also set a new world record for long-distance flight by a woman. We are proud of both of these people, and the team of volunteers and students who made this flight possible. The Anhauser-Busch Brewing Company underwrote the cost of constructing the prototype, which was called the Michelob Lite Eagle. If sufficient funds can be found, Professors Bussolari and Drela hope to try the over-water flight next spring.

The Wednesday noon Faculty Luncheon meetings continue to be popular. In the fall semester, each of the division heads presented a discussion of their view of the evolution of their technical specialty. This was followed by a series of discussion meetings about the educational consequences of the evolution. In the spring, we discussed two topics of general interest: the Manufacturing Initiative at MIT, and a special Master's degree program. We also discussed the long-term needs for Department computing, as well as several proposals to modify the Doctor's program. Professor Travis Merritt talked about the Freshman Program and Mr. Larry Beckley presented a new budget and accounting system that we are introducing into the Department. These meetings are well attended, and I believe they are a very effective way of stimulating discussion and improving communication among the Department faculty. Professor Markey did an outstanding job in making the arrangements for these meetings.

Each discipline continues to sponsor its own seminars and working groups. This activity is valuable for both teaching research assistants technical material and helping them to learn to listen critically and communicate more effectively.

Professor W.R. Sears gave the 21st Lester D. Gardner Lecture this April, entitled "Fifty Years of Aerodynamics: Colorful Characters at Their Best and Worst". The lecture was informing and witty, and we appreciate the time and effort that went into the preparation of it. The attendance was good, and helps to display the strong spirit of "community" among the Department's friends and alumni.
We had another community affair this spring: Professor Young organized a 25th reunion and celebration of the Man-Vehicle Laboratory. This, too, drew many alumni, former faculty, and leaders in the discipline who paid homage to this active laboratory.

Our undergraduate enrollment has continued to grow. The graduate enrollment, as a result of our desire to reduce the faculty work load, was down slightly.

**UNDERGRADUATE PROGRAM**

As shown in the table below, the undergraduate enrollment has continued to increase, being over 50 percent greater now than seven years ago.

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Undergraduate Enrollment Over the Last Seven Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomores</td>
<td>78</td>
</tr>
<tr>
<td>Juniors</td>
<td>70</td>
</tr>
<tr>
<td>Seniors</td>
<td>55</td>
</tr>
<tr>
<td>Totals</td>
<td>203</td>
</tr>
</tbody>
</table>

The current fraction of women in this year's graduating class is down sharply to 0.13, as compared with last year's fraction of 0.24. The average for all three classes is somewhat higher than before at 0.153.

Mr. Al Cangahuala was selected for the Doolittle Scholarship Award. Not only is he an excellent student, but he has also been an undergraduate teaching assistant, as well as a contributor to many other Departmental activities.

We have continued concern about our ability to educate large numbers of undergraduates. A number of interesting ideas have been suggested and will be explored in detail at a workshop in June.

About one-third of our faculty continues to be actively involved with freshmen in one way or another. We are pleased to be able to maintain this level of commitment in this important arena.

**GRADUATE PROGRAM**

As noted above, the number of graduate students has decreased somewhat. The total number is about 205, which is down by about ten percent from last year. We plan to continue this trend until the number of graduate students is about five per faculty member.

**FACULTY NOTES**

- Professor Edward F. Crawley received the Aeronautics and Astronautics Teaching Award.
- Professor Michael Giles was named an Edgerton Professor.
- Professor Norman D. Ham has been selected to be an Editor for Pergamon Press for a helicopter series.
- Professor R. John Hansman received an award for the best paper in thermal physics for the AIAA. His paper with M. Kirby was entitled "Experimental Measurements of Heat Transfer from an Iced Surface During Artificial and Natural Cloud Icing Conditions". He also received US Patent No. 4,628,736 entitled Method and Apparatus for Measurement of Ice Thickness Employing Ultrasonic Pulse-Echo Technique.
- Professor Belgacem Jery was named a "Presidential Young Investigator", with an accompanying discretionary research award of $250,000 over the next five years.
- Professor Paul Lagace is now a member of the American Society of Testing Materials Committee D30 to standardize testing procedures for modern composite materials.
- Professor Marten Landahl was elected Secretary General for the Engineering Science Research Program.
- Professor James W. Mar received the AIAA Structures and Materials Award for 1987.
- Professor Manuel Martinez-Sanchez was named to be a Session Chairman for the Goddard Memorial Conference.
• Professor Earll M. Murman was elected a Fellow of the American Institute of Aeronautics and Astronautics. He was also selected to be an Editor of the Vieweg Series "Notes on Numerical Fluid Mechanics".

• Professor Amadeo Odoni was selected to be an Editor of the Transportation Journal.

• Professor Theodore H.H. Pian was selected to be an Honorary Professor at the Changshi Institute of Railway Engineering.

• Professor Leon H. Trilling is now the Chairman of the Council for the Understanding of Technology in Human Affairs.

**OTHER MATTERS**

• Professors Crawley, Louis and Young will be on Sabbatical leave next year.

EUGENE E. COVERT
This department is changing its education and research programs to anticipate future needs. The emerging new technologies require engineers with multi-disciplinary knowledge and skills, the traditional technologies require engineers that can lead innovations to rejuvenate mature products, and society needs engineers who can be effective policy makers. The department will undertake an extensive revision of the undergraduate curriculum to prepare our students for the future.

The undergraduate enrollment has continued to decline slightly. A recent survey showed that about 75 percent of the S.B. graduates received post-graduate education in chemical engineering or in the professional schools of business and medicine, either immediately after graduation or after a few years in industry. The graduate student population has remained stable at the 220 level, with a further increase in the proportion of doctoral students. The quality of graduate students remains very high. An indication is that in the last five years, we have won 26 percent of all National Science Foundation Fellowships given to chemical engineers. We have placed 12 graduates as assistant professors in the last two years, in schools such as Princeton, University of California at Berkeley, Cornell, Delaware and MIT (mathematics and material science).

The H. P. Meissner Career Development Professorship was announced in February 1987, in honor of Emeritus Professor Meissner. The Practice School Endowment for Fellowships has gotten off to a fast start, and gathered about four million dollars towards the stated goal of eight million dollars.

A program for Toxic Substances has been organized to assume the cradle-to-grave responsibility of managing toxic substances, in conjunction with faculty from Civil Engineering and Applied Biological Sciences. The chemical engineering efforts are led by Professor Adel Sarofim and Senior Research Associate John Ehrenfeld. A laboratory of artificial intelligence for chemical engineering problems was organized as an industrial consortium with the name of LISPE under the direction of Professor George Stephanopoulos.

The H. P. Meissner Career Development Professorship was announced in February 1987, in honor of Emeritus Professor Meissner. The Practice School Endowment for Fellowships has gotten off to a fast start, and gathered about four million dollars towards the stated goal of eight million dollars.

A program for Toxic Substances has been organized to assume the cradle-to-grave responsibility of managing toxic substances, in conjunction with faculty from Civil Engineering and Applied Biological Sciences. The chemical engineering efforts are led by Professor Adel Sarofim and Senior Research Associate John Ehrenfeld. A laboratory of artificial intelligence for chemical engineering problems was organized as an industrial consortium with the name of LISPE under the direction of Professor George Stephanopoulos.

The year 1988 will be the centennial of the beginning of chemical engineering education under the leadership of Prof. Lewis Mills Norton as a program in the department of chemistry. The department is planning to host a Centennial Convocation to celebrate this event, and to look forward to the future of chemical engineering in the second century.

**UNDERGRADUATE PROGRAM**

The following table shows the trends in undergraduate enrollment:

<table>
<thead>
<tr>
<th></th>
<th>81-82</th>
<th>82-83</th>
<th>83-84</th>
<th>84-85</th>
<th>85-86</th>
<th>86-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomores</td>
<td>127</td>
<td>133</td>
<td>59</td>
<td>61</td>
<td>49</td>
<td>43</td>
</tr>
<tr>
<td>Juniors</td>
<td>104</td>
<td>112</td>
<td>105</td>
<td>47</td>
<td>69</td>
<td>49</td>
</tr>
<tr>
<td>Seniors</td>
<td>111</td>
<td>111</td>
<td>116</td>
<td>115</td>
<td>54</td>
<td>65</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>342</td>
<td>356</td>
<td>280</td>
<td>223</td>
<td>172</td>
<td>157</td>
</tr>
</tbody>
</table>

The job market has stabilized, with slack in the chemical and petroleum areas being compensated for by increased interest in other areas such as biotechnology and semiconductor fabrication. We anticipate sophomore registrations for '87-'88 to be between 40 and 45. Optimal sophomore registration is in the range of 60 to 80.

We have consolidated the changes made last year in our thermodynamics sequence (10.13 and 10.14) and in process design (10.36). Currently, we are in the middle of an extensive review of our entire undergraduate curriculum. The objective here is to update and refine our curriculum content to better build on the ever-changing content of the basic science subjects and to better prepare our students for the challenges of the changing technical world. We are also evaluating our curriculum in the context of the Institute's efforts to broaden and strengthen the humanities and social science components of the MIT education. This curriculum review will be completed by the Fall of 1987.

**Curriculum Revision Committee**

A committee chaired by Professor Lawrence B. Evans began a major review of the Department's undergraduate curriculum. The purpose of the review was to identify changes needed to respond to changing career opportunities anticipated for chemical engineers in the 1990's. A comprehensive
analysis was made of the present undergraduate program in which all required subjects both inside and outside the Department were broken down into modules, and a complete network showing the relationship of the modules was constructed. The preliminary results from the committee were reviewed at an all-day meeting, and the faculty and student representatives at Endicott House in June. Task Forces will consider various changes in the curriculum for implementation in the Fall of 1988.

GRADUATE PROGRAM

The following table shows graduate enrollment from 1982 - 1987.

<table>
<thead>
<tr>
<th></th>
<th>82-83</th>
<th>83-84</th>
<th>84-85</th>
<th>85-86</th>
<th>86-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masters</td>
<td>93</td>
<td>75</td>
<td>77</td>
<td>72</td>
<td>77</td>
</tr>
<tr>
<td>Doctoral</td>
<td>115</td>
<td>132</td>
<td>127</td>
<td>148</td>
<td>150</td>
</tr>
<tr>
<td>TOTAL</td>
<td>208</td>
<td>207</td>
<td>204</td>
<td>220</td>
<td>227</td>
</tr>
</tbody>
</table>

The total for 1986-1987 includes 63 foreign students, 29 female students, and 5 minority students (not including Asian Americans). The increase in the total number of students is primarily due to the increased number in the doctoral population. A growing number of students come here to obtain a doctoral degree instead of a master's degree.

In response to greatly increased interest in manufacture of integrated circuits, hazardous waste problems, and biotechnology, six new graduate level courses were offered this year. Prof. Herbert Sawin, in cooperation with the departments of EECS and Materials Science and Engineering, participated in developing the new laboratory and lecture course, 10.611J, Microelectronics Processing Technology. Prof. Adel Sarofim, working with Dr. John Ehrenfeld of the MIT Program on Hazard Substances Management, has developed the new lecture course 10.72J, Chemicals in the Environment: Sources and Control. Prof. Daniel I.C. Wang, with members of the faculty of Applied Biological Science, offered the course 10.56J Biotechnology of Mammalian Cells. Dr. Martin Yarmush offered two new courses during the year: 10.58, Structure Dynamics and Reactivity in Molecular and Cellular Biology, and 10.681, Immunotechnology. Prof. Alan Hatton has developed a new course, 10.55, Colloid and Surface Science.

The Practice School

Thirty-two students received a Master's degree in Chemical Engineering Practice last year. About 40 percent of these students continued on to our doctoral program, while the remainder was equally distributed between MIT undergraduates enrolled in our 5-year program and Master's candidates originating from undergraduate institutions other than MIT. This year two stations were operated: one in Albany, New York, with General Electric at its Noryl plant in Selkirk and its Silicones plant in Waterford, and another in Midland, Michigan, at Dow Chemical's major facility. The Midland Station was opened for the first time in August with a group of twelve students attending, and Assistant Professor Richard Helling serving as the Director. Starting January, 1987, Assistant Professor Jeffrey Feerer took over the Directorship in Midland while Rich Helling assumed a permanent position with Dow. Assistant Professor Robert Hanlon has been the Director at the Albany Station, and Assistant Professor Gregory Mehos has been appointed Director for the coming year.

As the Practice School enters its 70th year of operation, the program continues to represent MIT's unique contribution to internship education in chemical engineering at the graduate level. With its project work conducted at industrial field sites, the Practice School exposes young engineers to the evolving needs of our industry in developing their technical, communication, and managerial skills. The program's health and vitality is strongly influenced by our ability to provide financial aid to its students. Because industrial project work replaces a normal research thesis, the traditional academic method of funding research from government agencies is not appropriate for supporting Practice School students. The companies hosting the field stations provide aid to students while they are in residence, but the Cambridge course work portion needs financial sponsors. We are asking companies to sponsor fellowships at a commitment level of $15,000 per year for a three-year period. Presently we have 14 companies supporting the fellowship program providing about $210,000 annually. Alumni support in the form of endowed fellowships is also being pursued, and we are pleased to announce that over $4 million has been pledged already, which is halfway toward our long-term goal of $8 million. With a permanent endowment, the vitality of the Practice School program will be strengthened considerably as we can offer financial aid to students on a continuing basis and not have to rely on the renewed support from the private sector.

Artificial Intelligence

The Laboratory for Intelligent Systems in Process Engineering (LISPE) was formed within the Department of Chemical Engineering, under the direction of Professor George Stephanopoulos. The purpose of LISPE is to explore the use of artificial intelligence in expanding the scope of and offering novel...
approaches to the solution of problems in chemical process engineering. Twelve graduate students and two post-doctoral associates are investigating the design of molecules with desired properties, synthesis of preliminary process flowsheets, design of plant-wide control systems, planning and scheduling of process operations, and process trends analysis for continuous and batch chemical or biochemical processes.

The LISPE-Industry consortium on "Artificial Intelligence in Process Engineering" held its First Annual Symposium, May 26-27, 1987, at MIT with over 50 participants from 25 companies. The consortium was formed to foster interaction with industry in approaching meaningful problems and transferring the new technology from MIT to industrial practice.

BioSeparations Laboratory

The new BioSeparations Laboratory (BSL), which includes a fermentation and recovery pilot plant, has been made fully operational. It is used for research, as well as teaching undergraduates in 10.27 (Unit Operations) and 10.59J (Biochemical Laboratory). Experiments were initiated this Spring. The BSL was made possible through a major grant to Prof. Charles L. Gooney from Alfa Laval and funding for the Unit Operations Laboratory from BPEC.

Polymer Science and Technology

During 1986-87 the Interdepartmental Program in Polymer Science and Technology (PPST) was officially launched under the Directorship of Professor Robert E. Cohen. The program involves faculty from both the School of Engineering and the School of Science. Six students, enrolled in four different MIT departments, took the PPST core curriculum and completed the doctoral qualifying examinations in May, 1987. Six more students have been awarded places in PPST for the coming academic year.

Professors Robert E. Cohen and Ulrich W. Suter have teamed up with Professors Ali S. Argon and David M. Parks of Mechanical Engineering, and Professor Sidney Yip from Nuclear Engineering, to launch a major attack, both experimental and theoretical, on the problem of deformation, failure, and texture evolution during the deformation of semicrystalline polymers. The work is part of a $4 million grant to MIT from the DARPA-URI program.

Toxic Substances

The Department is developing educational and research programs to instill in students a concern for environmental and safety issues relating to chemicals throughout their life cycle. The students are being exposed to an increasing number of relevant case studies in their core courses, an annual invited lecture on safety or the environment in the Departmental Seminar Series, and are being provided with opportunities to study these issues in a broad interdisciplinary context through the Department's participation in the Institute-wide initiative on Chemicals in the Environment, consisting of courses on Sources and Control (Chemical Engineering), Transport and Fate (Civil Engineering), Human Health (Applied Biological Sciences), and Policy and Management (Urban Studies).

FACULTY

Ulrich W. Suter was promoted to Full Professor; T. Alan Hatton was promoted to Associate Professor and granted tenure.

Two new faculty appointments were made during the 1986-87 academic year. Assistant Professor, Daniel Blankschtein, who joined the Department in August of 1986, was appointed to the Texaco-Mangelsdorf Career Development Chair, to be held for three years. Karen Gleason will become the first Herman P. Meisner Assistant Professor of Chemical Engineering starting September of 1987.

A number of faculty achievements during the year deserve special mention:

Professor Robert C. Armstrong has been elected to serve on the Executive Committee of the Society of Rheology. His two new books, Dynamics of Polymeric Liquids, Vol. 1: Fluid Mechanics, with R.B. Bird and O. Hassager, and Dynamics of Polymeric Liquids, Vol. 2: Kinetic Theory, with R.B. Bird, C.F. Curtiss, and O. Hassager, were published by Wiley and Sons.

Professor János Beár was the recipient of the Combustion Institute's senior award, the Alfred Egerton Gold Medal. He was the Coal Science Lecturer of the British Coal Research Association and was awarded their Gold Medal. He was also elected Honorary Member of the Hungarian Academy of Science.

Professor Howard Brenner was the Stanley Katz lecturer at the City College of New York and Lindsay Lecturer at Texas A & M University. He assumed the position of co-Editor-in-Chief of PhysicoChemical Hydrodynamics (PCH), an international journal published by Pergamon Press.
Professor Robert A. Brown received the Allan P. Colburn Award from the AIChE in recognition of his research achievements in the modelling of crystal growth processes and the fluid mechanics of viscoelastic liquids. He was also honored as the Allan P. Colburn Lecturer at the University of Delaware in October 1986.

Professor Clark K. Colton received the Gambro Award (now called the Nils Alwall Award) from the International Society for Blood Purification. The award was presented at a symposium in his honor in Osaka, Japan.

On September 17, 1986, the keynote speaker at the joint AIChE - CIChE Conference on Modern Chemical Engineering Technology was Professor Lawrence B. Evans.

Professor Adel F. Sarofim delivered the first Hottel Lecture at the Combustion Institute meeting in Munich, Germany, in August of 1986. He also delivered the William N. Lacey Lecture at the California Institute of Technology in February, 1987.

Professor Herbert H. Sawin received The Thinker Award presented by the Tegal Corporation in recognition of contributions to plasma etching technology; in particular, for innovative characterization and modeling of plasma etching processes.

The 1987 Marchon Lecturer at the University of Newcastle, England, was Professor Gregory Stephanopoulos. He also served at the Editorial Boards of Biotechnology Progress and Mathematical Biosciences.

Professor Ulrich W. Suter was appointed as a member to the National Materials Advisory Board Committee on Liquid Crystalline Polymers, a committee of the National Research Council.

For the second consecutive year, Professor Jefferson Tester was chosen to receive the Department's Outstanding Faculty Award for excellence in teaching and research. Professor Tester served on the National Research Council Committee on Geothermal Energy Technology and the U.S. Energy Department's Review Committee on Advanced Technology Program.

Professor James Wei, Chairman of the Department, was elected Vice President of the American Institute of Chemical Engineers, and will become President in November of 1987.

STUDENTS AND STAFF

Institute-Wide Awards

Michael R. Gobler ('89) and Jeffrey D. Pribble ('89) were recipients of the two Eastman Kodak Scholarships awarded to the MIT School of Engineering for academic and personal excellence. Maria Tsiakkas ('87) received the Association of MIT Alumnae Senior Academic Award (AMITA) which is given for academic excellence and professional achievement to a senior woman. Four students were elected to Tau Beta Pi: Tammy L. Almasian ('88), Philippe S. Fusco ('87), Susan C. Noe ('87), and Lisa A. Vingerhoet ('88).

Departmental Awards

Maria Tsiakkas also received the Robert T. Haslam Cup for outstanding professional promise in Chemical Engineering. The Dow Outstanding Junior Award recipient was Thomas P. Kronenberger for achievement in scholarship, leadership, and campus activities. The AIChE Annual Chapter Scholarship Award for highest scholastic performance through the first two years was given to Lisa A. Vingerhoet ('88). The Texaco Philanthropic Foundation Scholarship was given to Tammy L. Almasian ('88) and Victor H. Barocas ('88) for excellence in academic performance. The American Institute of Chemists annually recognizes outstanding seniors demonstrating leadership, character and scholastic achievement. This year's recipient was Mark A. Jensen. The oldest prize in the Department, the Roger deFriez Hunneman, which recognizes outstanding scholarship and research, went to Farzan A. Riza ('87). Brian S. Gorin ('86) was awarded the Reinhold Rudenberg Memorial prize for an outstanding undergraduate thesis relating to energy conversion. Linda C. Marinilli and Hoi Man Siu (seniors) received the Chemical Engineering Department Special Service Award for their joint work as president of the Student Chapter of the AIChE.

Graduate students receiving awards were Godavarthi S. Varadarajan and Reza Rahaman. Godavarthi was honored for exemplary performance in his project work at the Practice School with the Rosemary J. Woltowicz Award. The ChemE Graduate Special Service Award for unselfish contributions to departmental activities was given to Reza.

The Outstanding Employee Award was given to Gabrielle Joseph for exceptional service to the Department and its students.

JAMES WEI
INTRODUCTION

This has been an important year for the profession and for the Department of Civil Engineering. The surge of activities in hazardous waste management; improved construction technology and management; use of the computer for increased quality control, innovative approaches and better integration in design, construction, operation, and transportation; has created a boom market for our graduates and our research programs. MIT Civil Engineering, through its innovative educational programs, faculty involvement in the profession, and robust and path breaking research programs, continues to provide leadership for the profession as it goes through a considerable metamorphosis. New ideas for productivity increases, technologic innovation and professional foci are changing the way civil engineering is being carried out and the magnitude of its assignments for the needs of our society. The Department, through its careful planning over the last five years, is well prepared and well positioned to help with this important evolution as is evidenced in the following sections detailing our activities over the past year.

Undergraduate Education

This is the first year that the Department's new Undergraduate Program is in place and operational. We have added to our common sophomore year unified core of basic materials in solid mechanics, economics, fluid mechanics, structural engineering, fluid dynamics, and ecology for all our designated programs. New electives in engineering computation have been added as well.

The Department has also put in place a new Undesignated Course IA option in Engineering Systems and Computation (ESC) designed for students who wish to have a broad based systems and computation program but do not wish to satisfy all of the requirements for the SB in Civil Engineering. The program is focused on software and system analytic tools for dealing with large and complex engineering issues. It prepares students for careers in diverse fields such as engineering, model building, engineering application of robotics, automation in large scale system and data acquisition and handling. The program is designed for people who wish to do further study in application areas such as transportation, energy, the environment, and logistics, as well as those planning work in business management, operations research, planning, and engineering project management.

Planning is now complete for a second IA option in Environmental Engineering which will begin in Fall 1987. Building on the Department's strengths in fluid mechanics, environmental chemistry and biology, ecology and hydrology, students with guidance from our faculty can build programs over an interdisciplinary spectrum drawing on Chemical and Mechanical Engineering (sources and control), Applied Biological Sciences (toxicology and health effects), and policy aspects (Urban Studies, Economics, Management).

Our teaching program continues to provide service subjects for the Institute as a whole. Subject 1.00 Introduction to Computer Systems is a popular subject which now teaches over 350 students per year and is now the largest non EE basic Institute computer subject. We have also taken over responsibility for the School of Engineering's school-wide subject 1.12 Computer Models of Physical and Engineering Systems.

Graduate Program

The Department organizes its graduate programs around activities in three divisions: Transportation Systems, Water Resources and Environmental Engineering, and Constructed Facilities. In addition, a cross-cutting Center for Construction Research and Education has been formed drawing on division faculty to address the problems of the construction industry. Significant events in each area are reported as follows:

Center for Construction Research and Education (CCRE)

The major event of this year is the funding of a major new Research Center in Civil Engineering at MIT. Under the leadership of Professor Fred Moavenzadeh, the Program for Advanced Construction Technology will provide almost $15 million over the next five years for fellowships for US PhD candidates, equipment, and research programs. The Program's research will focus on four main areas: new materials for construction, intelligent engineering systems and automation, and robotics and non-destructive testing. We have already received $1 million of new experimental and computer equipment and have attracted ten excellent students for the fellowship program. Involved in the research are Professor Robert Logcher in Intelligent Project Management Systems; Professor Victor Li in New Composite Materials for Construction, Professor Lorna Gibson in Composite Panels for Construction; Professor S. Shyam Sunder for work on Failure Mechanisms in Construction Materials; Research Associate Dr. Kenneth Maser for work on the Instrumentation and Interpretation Aspects of Non Destructive Testing in Large Civil Works; Principal Research Associate

201
Mr. Michael Markow in Ceramic Materials; and Professor Sue McNeil in Uncertainty in Infrastructure Management Decision Making.

A consortium of five New England states has increased its research in infrastructure at MIT. Dr. Kenneth Maser is carrying out research via a field experiment on nondestructive testing of Bridge Decks. This summer he will survey 20 old bridge decks slated for destruction. After the tests the materials will be destructively tested to compare actual with predicted conditions. The momentum developed by this and other research has increased student interest and participation in the Center's activities. Formed in 1982 for interaction with the construction industry, this year the Center's educational program has attracted well qualified graduate students and continues to produce unique, well trained professionals for the industry and a cadre of research PhD candidates who are helping to refocus construction activities in academia in the US and around the world. For the first time this year an industrial firm, Parsons, Brinkerhoff, Quade and Douglas, took on and presented a subject in case studies in heavy construction. The subject reviews five major civil engineering projects in a timely manner and within the cost limits that the owner was willing to accept. The Army support, plus activities such as the case studies subject, roundtables, and seminars, indicate that the direction and thrust of our program in construction engineering and management is being appreciated and is now receiving the attention that it deserves from the US construction industry.

**Constructed Facilities Division**

The Division continues its developments in the new initiative areas of advanced materials for construction, computer aided engineering and construction automation as well as planning for the future of geotechnical engineering at MIT. In the area of construction materials, research has increased explosively in the past three years. Five full-time faculty members (Professors Li, Shyam Sunder, Buyukozturk, Gibson, and Einstein), where before we had none. Major projects under the US Army Research Office, the US Army Corps of Engineering Construction Engineering Research Laboratory, the Department of Energy, the National Science Foundation, and industry sponsorship have expanded both the scope of materials work and the laboratory facilities within which the work is conducted. All construction materials research resides under the umbrella of the Remergence Laboratory and has been greatly helped by equipment grants through the ARO program for advanced construction technology. Development has begun this year on a large cold temperature facility for ice mechanics research, and consortium funding has been arranged for research on refractory materials. An Engineering Research Center (ERC) proposal to the National Science Foundation involving major funding and industrial cooperation has been submitted for work on construction materials.

Computer aided engineering is an area of considerable interest and challenge as we seek ways to make generic contributions to design and analysis approaches. The area has enjoyed great success attracting students and research funds, but has outgrown the plan behind its development. Planning for the future of CAE remains among our highest priorities, under funding from the ARO and through major equipment donations, the intelligent engineering systems laboratory has grown rapidly. Computer room floor space tripled this year adding two dozen engineering work stations from Sun, Apollo, DEC, Tektronics, and IBM, and a number of peripherals. Major projects are underway on expert systems for applications to maintenance management, design checking, constructability, and other problems. Other major efforts are the non destructive evaluation of pavements and bridges; geographic information systems and intelligent data bases for design construction interfacing. Tutoring programs for the computer aided teaching of structures (CATS) project remains a major and highly visible activity.

**Geotechnical Engineering** has always been a major leadership area for MIT. We have written a new five year plan this year singling out environmental geotechnology, computer aided geotechnical engineering, and remote in situ (e.g. geophysical) testing. Each of these areas enjoys rapidly advancing technology, complementary programs within the department, and strong research support. The area of geotechnical construction technology is also identified as important for the future, but given lower priority.

**Transportation Systems Division**

This year TSD continued with the momentum and renewal process which it started in the last year. The number of students and their quality remained high, and the large increase in the number of students attending the TSD basic courses experienced last year has been maintained. The Division continued to increase its funded research base, and the number of Research Assistants funded on these projects. Computational facilities have been upgraded with the purchase of a microvax workstation II, two Macintosh microcomputers, several IBM-compatible high end micro computers, and other peripheral equipment as well as large amounts of software.

On the academic side, the year was devoted to fine tuning many of the courses that were started and restructured last year, and to starting a few others. The year has culminated in the conclusion of a successful search for a faculty member in the computation/logistics area. We have hired Haris Koutsopoulos who will be teaching in the computation area, and developing shipper-related logistics research. The challenge for the Division in the coming years is to continue its quest for high academic quality and pursuing the state of the art in research with ever increasing vigor.
The Water Resources and Environmental Engineering Division covers areas of hydrology and water resources, aquatic sciences, environmental engineering, and hydrodynamics and coastal engineering. It serves as the Department's water-related activity center and as an important focus on the water environment for the entire Institute. During 1986-87 WR&EE continued steady progress towards its major long term goals.

The new undergraduate degree program in Environmental Science and Engineering became a reality during this period and is attracting students and Institute interest. At the graduate level, as a result of last year's discussions on doctoral program requirements, a series of guidelines not only related to doctoral programs but to exams and graduate student life in general have been developed.

Some changes in graduate course offerings occurred during this past year. Prof. Frank Perkins offered a new, and successful, Engineering Hydrology course. Subjects 1.712 Sampling, Synthesis and Forecasting of Hydrologic Process, and 1.732 Probabilistic Methods for Water Resource Management will, from now on, be offered as a coordinated pair on alternate years. A new course dealing with advanced topics in hydrology offered by Prof. Ignacio Rodriguez-Iturbe has been instituted. This activity has been received with a lot of enthusiasm by faculty and students in the area.

In research during this past year, the Division has largely concluded that the times demand its involvement in large, "research center," initiatives. This is somewhat in contrast to our highly successful individual research efforts (1985-86 research expenditures were 3.3 million dollars, 1986-87 expenditures were again about 3.3 million dollars, exact figure is not yet available). This is the first year in the near past with no significant increase in research expenditures. Discussions about submitting an engineering or science center proposal to NSF have been ongoing. Partnerships (i.e., Princeton) and topics (i.e., hazardous waste, groundwater hydrology, hydrometeorology) have been discussed.

In research during this past year, the Division has largely concluded that the times demand its involvement in large, "research center," initiatives. This is somewhat in contrast to our highly successful individual research efforts (1985-86 research expenditures were 3.3 million dollars, 1986-87 expenditures were again about 3.3 million dollars, exact figure is not yet available). This is the first year in the near past with no significant increase in research expenditures. Discussions about submitting an engineering or science center proposal to NSF have been ongoing. Partnerships (i.e., Princeton) and topics (i.e., hazardous waste, groundwater hydrology, hydrometeorology) have been discussed.

Initiatives have been formalized with proposals to NIEHS for a center dealing with hazardous waste issues (in conjunction with Applied Biological Sciences and within the framework of the MIT-wide hazardous waste initiative) and with a proposal to Federal and state agencies for a consortia of universities to study Boston Harbor/Mass. Bay problem.

An agreement with the University of Puerto Rico to participate in a Minority Research Center of Excellence for Natural and Man-Made Hazards Mitigation was reached. The proposal was submitted, with a strong possibility of success. Prof. Bras will be part of the Advisory Committee of that Center.

A similar cooperative agreement was reached, and funding is expected, with the University of Florence to study hydrogeological disasters in Italy, particularly those related to the Arno River in Florence.

Interactions with other institutions and departments at MIT have also been on the rise, as planned. Besides those mentioned above we can add continuing and increasing work with Woods Hole Oceanographic Institution, Research Cooperation with Lamont Doherty Laboratories, two research contracts in conjunction with the Center of Meteorology and Oceanography, cooperation in research with the University of New Mexico, cooperation with the University of Mexico.

Work on field and experimental facilities continues. The call for a field facility in the five-year plan remains somewhat unattended except that the involvement with the USGS in a Cape Cod site for groundwater transport is now a reality. Some conversations to get involved with an industrial, existing, hazardous waste site, are ongoing.

Through the efforts of Professors C. C. Mei, Kenneth Melville, and Ole Madsen, and funding from a variety of sources, the two-dimensional wave tank is almost a reality. The computer local area network is in place and operating well, providing essentially all academic and research computer needs.
Faculty and Staff

Professor Lynn Gelhar of the Water Resources and Environmental Engineering Division was on sabbatical leave during the 1986-87 Academic Year.

One resignation was received: Associate Professor Amr Azzouz resigned to take a position as Associate Dean at Kuwait University.

Promotions: Professor Lorna Gibson, a specialist in cellular and composite materials for construction, to Associate Professor; Professor Philip Cachwand, a specialist in the fate of organics in the environment, was granted tenure; Professor Yosef Sheffi, a specialist in large scale transportation network equilibrium and in logistics, was promoted to Professor; Professor Moshe Ben-Akiva, a specialist in demand estimation and prediction in transportation systems, was promoted to Professor.

Service to the Institute

Civil Engineering faculty continue to provide a considerable service role to the Institute. Professor Daniel Roos, Japanese Steel Industry Professor of Technology, is Head of the School of Engineering's Center for Technology, Policy, and Industrial Development; Professor David H. Marks is providing leadership for the Institute's coordination of activities in hazardous substances management; Professor Joseph Sussman is Head of the Center for Transportation Studies; Professor Fred Moavenzadeh, William E. Leonard Professor of Engineering, heads the Institute's Technology and Development Program; Professor Richard deNeuville heads the Technology and Policy Program, the educational program of CTPID; Professor Herbert Einstein is Head of the multi department Remergence Laboratory effort; Professor Frank D. Perkins serves as Dean of the Graduate School; and Professor Steven Lerman is Head of Project Athena, the Institute's major initiative in computers in education.

Department Administration

Department Head, David H. Marks
Head, Water Resources and Environmental Engineering Division, Rafael Bras
Head, Transportation Systems Division, Yosef Sheffi
Head, Constructed Facilities Division, Gregory Baecher
Head, Center for Construction Research and Education, Fred Moavenzadeh
Admissions Officer, Keith Stolzenbach
Undergraduate Officer, Ole Madsen
UROP Coordinator, Harry Hemond
IAP Coordinator, Moshen Baligh
Student Chapter ASCE, Lorna Gibson
Chi Epsilon, John Germaine

Important Events for the Faculty

Professor Gregory Baecher, CFD, is President of the New England section of the Society for Risk Analysis.

Professor Moshen Baligh has been chosen as the 1987 winner of the American Society of Civil Engineers' James R. Croes Medal for his paper entitled "Strain Path Method."

Professor Moshe Ben-Akiva has become an Associate Editor of the Journal of Regional Science and Urban Economics.

Professor Rafael Bras has taken over the leadership of the MIT MITES Program (Minority Introduction to Engineering Sciences). The program brings outstanding high school juniors to campus for intensive introductions to science and engineering. A high percentage of the students in the program continue on as undergraduates at MIT.

Professor Oral Buyukozturk has formed a 20 company industrial consortium in the field of material characterization and development of a knowledge system for the analysis and design of refractory linings for a wide variety of process vessel applications.

Michael Celia, Assistant Professor in the Water Resources and Environmental Engineering Division, and a specialist in ground water modeling, won an NSF Young Presidential Investigator Award. This prestigious award provides for research funding for up to $100,000 per year for five years. He has also been awarded an MIT Edgerton Professorship designated for young faculty of exceptional promise, and is working on a book in ground water modeling with Professor William Gray of Notre Dame.

Sallie W. Chisholm, Professor in the Water Resources Division, has expanded her biology work to include questions of ground water microbiology. She is serving as Associate Chair of the MIT faculty as well as being deeply involved in the current revision of the MIT curriculum.
Richard deNeufville, Professor in the Transportation Systems Division, celebrates his tenth year as founder, and head of the MIT Technology and Policy Program. The Program attracts 30 top notch graduate students per year in a two year Masters level degree program aimed at producing engineers and scientists with a wider purview of the intersection of technology and policy. He won the Department's award for most effective teaching this year.

Professor Peter Eagleson continues in his role as President of the American Geophysical Union.

Professor Herbert Einstein is co-editor of the Journal of Rock Mechanics and Rock Engineering, and is Director of the multi department Remergence Laboratory at MIT.

John Germaine, Lecturer in Geotechnical Engineering, has devoted considerable effort to the Remergence Laboratory, and is actively involved in the Standards Sub-Committees of the American Society of Testing Materials.

Professor Lorna Gibson holds the Edgerton Chair this year, and will be the Gilbert T. Winslow Career Development Professor for the next two years. She is finishing a book on cellular materials with Professor Michael Ashby of Cambridge University.

Professor Philip Gschwend is finishing up a book on organics in the environment with colleagues at ETH in Zurich, Switzerland.

Professor Donald R.F. Harleman is a 1987 Alumni Fellow at Pennsylvania State University and is writing a book on transport processes in environmental engineering.

Professor Harold Hemond continues work on instrumentation for an in situ ground water probe in support of the Department's and Institute's initiatives in the hazardous waste area.

Thomas Humphrey, Lecturer in Transportation and a member of the Center for Transportation Studies, leads the Institute's participation in a consortium of five New England states providing research for infrastructure maintenance and rehabilitation.

Professor Charles C. Ladd gave the Terzaghi Lecture "Stability Evaluation During Staged Construction" at the October 1986 ASCE meeting and at several other universities in 1987. The lecture will be taped and distributed by ASCE; a first for that organization.

Victor Li, Associate Professor in the Constructed Facilities Division, continues his work on new fiber reinforced construction materials with a new project in ceramics for building applications such as bridge deck replacement.

Professor Robert Logcher has provided leadership in our Intelligent Engineering Systems Laboratory.

Kenneth Maser, Research Associate, has been successful in establishing a strong program in the use of non destructive testing techniques such as thermography, laser dopler, and ground penetration radar for evaluation of infrastructure.

Carl Martland, Principal Research Associate in Transportation, is President of the Transportation Research Forum.

Professor Dennis McLaughlin is a member of the National Academy of Sciences Committee on Groundwater Contamination Modeling.

Professor Chang C. Mei has been elected to the National Academy of Engineering and won the Rosenstiel Award for Contributions in Applied Marine Physics awarded by the Rosenstiel School of Atmospheric and Marine Sciences of the University of Miami.

Professor Sue McNeil has been awarded a National Science Foundation Young Presidential Investigators Award with five years of funding at $100,000 per year in the area of infrastructure management. This funding includes industrial matching funds from the Burlington Northern Railroad.

Professor Fred Moavenzadeh received the National Society of Professional Engineers 20th Annual Journalism Award for a paper entitled "Construction's High Technology Revolution" and was named a distinguished engineering alumni by Purdue University.

Professor Francois Morel gave the keynote address at the Symposium on Trace Metal Specification sponsored by the Canadian Chemical Society, and continues his work on his book on sorption phenomena in natural waters.

Professor Yosef Sheffi won second place in the TIMS (The Institute for Management Sciences) Edelman Prize Award paper competition.
Professor Alex Slocum, Macomber Career Development Chair holder, has completed several automated machines for interior wall installation as a demonstration of machines for productivity increases in the construction industry. He has received several awards from the National Bureau of Standards for his robotic developments, as well as a Certificate of Recognition from the Society of Manufacturing Engineers. He is working on a book on automation in the construction industry.

Professor Duvvuru Sriram is Co-Editor of the *International Journal for AI In Engineering* and has published a book on *Knowledge Based Approaches to Structural Design*. Next year a co-authored book with Professor Steven Fenves, of Carnegie Mellon University, on knowledge based expert systems for engineering will be completed.

Professor Keith Stolzenbach has helped to organize a Boston Harbor/Mass Bay University Research Consortium to focus joint research on problems in these areas.

Professor S. Shyam Sunder has developed a major new experimental facility for cold regions testing. This will contribute to his extensive work in ice deformation and failures for ice as a construction material in the artic, and as an indicator of such failure in other construction materials. He is the current holder of the Winslow Career Development Chair and will hold the Doherty (Sea Grant) Career Development Chair in the fall.

Professor Daniele Veneziano is a member of two National Research Council committees (on seismic risk hazard analysis and on earthquake loss estimation).

Professor Robert Whitman has won the Terzaghi Award of the American Society of Civil Engineers. His newly installed centrifuge for studying earthquake results is already showing promising results.

Professor Nigel Wilson was the Co-Chair of the Tenth International Symposium on Transportation and Traffic Theory held at MIT this year.

DAVID H. MARKS
Department of Electrical Engineering and Computer Science

After a decade of relatively high undergraduate enrollments in Electrical Engineering and Computer Science (EECS), it now appears that the incoming class of sophomores will number only 250, a significant reduction from the nearly 330 sophomores this past year, and under our goal of 270. Several reasons for the decline have been proposed. For one, the new class will contain about 37 percent women and women have traditionally majored in engineering fields at lower rates than men. There is some validity to this theory, but not as much as some would have guessed since about 27 percent of the incoming EECS class is women. A theory that seems very plausible to us is that a significant part of the reduction is a delayed reaction to the slump in the computer and electronics fields in the past two years. In any case, continued lower sophomore class sizes should result in better education for our students and a less harried lifestyle for our faculty and staff.

Last November Professors William M. Siebert and Louis D. Smullin of the department's Life Long Education Committee hosted a two-day meeting for heads of Electrical Engineering departments. The topic was the need for life long education for EECS professors. This meeting resulted in the introduction of about half a dozen one- and two-week courses around the country in the summer of 1987. Funding for these courses came from industry (Bell Labs, Texas Instruments, Hewlett-Packard, and IBM all offered courses), the National Science Foundation, the Sloan Foundation and from a fund specifically earmarked for Life Long Education established by Mr. and Mrs. Howard Vollum in the EECS department. Three of the courses offered around the country will be versions of the department's 6.001 Structure and Interpretation of Computer Programs, presented in tutored video instruction format.

A major change in our undergraduate subjects was the introduction of about 45 new Hewlett-Packard "Bobcats" in our subject 6.003 Signals and Systems. These high performance personal computers run the SCHEME system taught in 6.001. They permit one to run signal processing algorithms in the lab associated with 6.003.

A School of Engineering committee, chaired by Professor David Marks, head of the Civil Engineering department, has been reexamining the role of the thesis in the Masters program. We expect the committee will recommend that departments be permitted to accept projects in lieu of theses for the SM degree. This may also permit the introduction of industrially sponsored theses in addition to our VI-A Internship Program. This issue is likely to be a significant one in the coming year.

UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 1,100 in 1986-87, with about 67 percent in the Electrical Engineering Program and 33 percent in the Computer Science Program. The total represents a decrease of about 35 students from the previous year. As a result of a variety of efforts aimed at reducing the number of our undergraduates, 330 sophomores were enrolled in the department this year. This was up from the 320 students who enrolled in the department the year before. Fortunately, initial estimates indicate that a sophomore class of about 250 students will enter the department in the fall of 1987, where we had anticipated at least 300. This is the first time undergraduate enrollments have dropped to, let alone been fewer than, our target of 270 students per class.

The following prizes and awards were won by our students. The Ernst A. Guillemin Prizes for the outstanding SB theses in Electrical Engineering were awarded to Robert A. Atkins of Lynnfield, MA (first prize), Elizabeth A. Miller of Stow, MA (second prize). Honorable mention went to Dhimat-Apurva Bhatty of Tampa, FL and Mordechai B. Fester of Miami Beach, FL. The new David Adler Memorial Prizes for undergraduate theses in Electrical Engineering were presented to Frederick P. Herrmann of Birmingham, MI (first prize), Achal Aggarwal of Burlington, MA (second prize) and Avinash S. Lele of Burlington, MA (honorable mention).

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by Yang Meng Tan of Singapore. The new Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to Jennifer Hunt of Vaud, Switzerland. The George C. Newton Prize for the best undergraduate laboratory project was awarded jointly to Lawrence M. Candel of Jericho, NY, and Adam L. Schwartz of Danville, CA. The 6.004 design prize was won by Andrew Shaw of Broadview Heights, OH.
A General Motors Scholarship for academic excellence was awarded to Cynara C. H. Wu of Mclean, VA. Janet L. Pan of Flushing, NY was one of two recipients of the Association of MIT Alumnae Awards for the highest level of academic excellence. The Albert G. Hill Prize for high academic standards and continued contributions to improvements of the quality of life for minorities at MIT was presented to Helena G. Cragg of New York, NY. Patricia A. Zietler of Sharon, PA was one of the two winners of the Laya and Jerome B. Wiesner Award for achievement in the creative and performing arts.

GRADUATE PROGRAM

In September, 1986, there were 624 graduate students enrolled in the department. Of this number, 199 were newly admitted. About 20 percent of the total were foreign nationals. The department supported 289 Research Assistants, and 114 Teaching Assistants. In addition, there were 128 fellowships including 32 National Science Foundation Fellows and 11 Hertz Fellows. The remaining students had industrial or foreign government support or were using their own funds.

During 1986 the department awarded the following graduate degrees: 159 Masters of Science, 27 Electrical Engineers, and 49 Doctorates.

The department received 1,890 applications for the 1987-88 year. The applicants were generally excellent and 283 were admitted, of whom we expect 188 to register for next fall.

A number of departmental awards were made to graduate students for excellence in teaching. Ann W. Morgenbinder, of Wellesley Hills, MA, received the Carlton E. Tucker Award, while Thomas K. Masotto of Federal Way, WA, received the Harold L. Hazen Award.

Frederick C. Hennie, III Awards for excellence in teaching were presented to Philip F. Bagwell of Atlanta, GA; Albin J. Gasiewski of Independence, OH; Karen E. Walrath of Stow, MA, and Karla V. Ballman of Somerville, MA. Katherine Yelick was awarded promotion to Instructor-G in recognition of her demonstrated teaching abilities and services to the department.

VI-A INTERNSHIP PROGRAM

The department's VI-A Internship Program, in its 69th year, continued both its popularity and excellence in performance this year. During the annual selection process the participating companies interviewed 172 sophomore applicants representing 57 percent of the EECS sophomore class. Unfortunately, the continuing departmental restriction of the overall size of VI-A limited the program to only 87 new openings.

There was also some change in the mix of participating companies this year. The Naval Surface Weapons Center renewed its participation after a three year hold period and has accepted two new students to start in the summer of 1987. Both Medtronic, Inc. of Minneapolis, MN, and Fairchild of South Portland, ME, decided to discontinue their participation and did not make new offerings available this year. Nor did RCA's Sarnoff Laboratory participate in this year's selection process due to uncertainties arising out of the purchase of RCA by the General Electric Co. There is no problem with the present students continuing their participation through completion of the program, however.

During the year 89 VI-A students completed their education in the program, 66 of these with the Master's degree and 23 completing at the Bachelor's degree level.

The continued excellence of VI-A students is attested to by the number receiving awards at the Institute's annual Awards Convocation and at the department's annual Spring Social. Listed alphabetically: Robert G. Atkins, EECS Guillemin Award for the outstanding undergraduate thesis; Joseph E. Bondaryk, Honorable Mention for the Frederick G. Fessett, Jr. Award given by MIT; Lawrence M. Candell and Adam L. Schwartz, George C. Newton, Jr. Award by EECS for an undergraduate laboratory project; Janet L. Pan, MIT award by the Association of Alumnae; Stephen J. Ponzi, 1987 Burchard Scholar in the School of Humanities and Social Science at MIT; and Katherine A. Yelick, promotion to Instructor-G for excellence in teaching.

Awards from outside the Institute went to Denice D. Denton, recipient of a national Presidential Young Investigator Award; Carey M. Rappaport, recipient of the 1986 H. A. Wheeler Prize of the IEEE, and Ann N. Tulintseff, a second prize in the student paper competition at the USNC-URSI National Radio Science Meeting, Boulder, CO.

This year marks the completion of eighteen years as Director of the VI-A Internship Program by John A. Tucker. Joining MIT in February 1956 from Bell Labs and the Bell System as assistant to then department head Professor Gordon S. Brown, he became MIT's first Administrative Officer in 1962 and accepted the VI-A Directorship in June 1969 under then department head Professor
Louis D. Smullin. Mr. Tucker's tenure included supervision of a tremendous growth in enrollment in the program, and many changes brought about by it. He will continue to be an advisory source to the department on VI-A matters while serving in a broader new position as Special Assistant to the Department Head for VI-A.

Taking over as Director of the VI-A Program, July 1, 1987, will be Mr. Kevin J. O'Toole, who was appointed Associate Director in August 1985. An alumnus of MIT (1957), Mr. O'Toole holds the SM in Naval Architecture and Marine Engineering and the degree of Naval Engineer. He served as Professor of Naval Architecture and Director of the Ocean Engineering department's educational program for Naval Officers from 1973-1978, when he retired from active duty as Captain, U.S. Navy. Prior to joining VI-A, Mr. O'Toole was, from 1978-1985, Technical Officer of the MIT Technology Adaptation Program, involving cooperation with Cairo University in Egypt.

RESEARCH

Most research of our faculty is performed in interdepartmental laboratories. We estimate the total FY87 research volume on projects of which our faculty or research staff members are in charge to be over $46 million, of which only $5.3 million takes place under the jurisdiction of the department. The bulk of the balance is allocated among the following interdepartmental laboratories associated with EECS.

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>$Million (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Intelligence Laboratory</td>
<td>7.9</td>
</tr>
<tr>
<td>Laboratory for Computer Science</td>
<td>9.4</td>
</tr>
<tr>
<td>Laboratory for Electromagnetic and Electronic Systems</td>
<td>2.5</td>
</tr>
<tr>
<td>Laboratory of Information and Decision Systems</td>
<td>2.5</td>
</tr>
<tr>
<td>Research Laboratory for Electronics</td>
<td>8.7</td>
</tr>
<tr>
<td>Plasma Fusion Center</td>
<td>9.2</td>
</tr>
</tbody>
</table>

In addition to the laboratories noted above, faculty research is also performed in other departmental or MIT-affiliated laboratories, namely: Energy Laboratory, Operations Research Center, Center for International Studies, Center for Materials Science and Engineering, Lincoln Laboratory, Francis Bitter National Magnet Laboratory, and Biomedical Engineering Center for Clinical Instrumentation (see Health Sciences and Technology (HST) Research Activities). Information on the work of all the interdepartmental laboratories mentioned above appears in other portions of this report, dealing separately with each one. However, the MIT Microsystems Research Center and Microsystems Technology Laboratories are departmental in organization and therefore report below the highlights of their research for the past year.

MICROSYSTEMS RESEARCH CENTER (Professor Paul Penfield, Jr.)

MIT research in microsystems is an interdisciplinary, interdepartmental enterprise that started about 1978, and is coordinated by the Microsystems Research Center. The actual research is carried out in several departmental and interdepartmental laboratories, including the Microsystems Technology Laboratories (MTL), the Submicron Structures Laboratory (SSL), the Research Laboratory of Electronics (RLE), the Artificial Intelligence Laboratory (AI), the Laboratory for Computer Science (LCS), the Laboratory of Information and Decision Systems (LIDS), and the Center for Materials Science and Engineering (CMSE).

This year the level of research exceeded $9 million, and the technical areas included electronic materials, submicron structures, integrated-circuit processing and devices, VLSI circuits, design automation, architecture, and VLSI theory. This research is described in other sections of this report by the individual laboratories conducting the research.

Coordination activities carried out by MRC include a weekly VLSI seminar series, a unified VLSI memo series, and a VLSI research review each semester. Special events also occur from time to time: this year a research workshop on Computer-Integrated Manufacturing for Integrated Circuits was held at MIT, with active participation from several universities, and jointly sponsored by the Defense Advanced Research Projects Agency (DARPA) and the Semiconductor Research Corporation (SRC). And a computer tape containing MIT VLSI CAD programs and other tools was released this year.
The facilities that enable some of this research are supported in part by the members of the MIT Microsystems Industrial Group (MIG), including Analog Devices, Incorporated, AT&T, Digital Equipment Corporation, Eaton Ion Beam Systems Division, GCA Corporation, General Electric Company, General Motors Corporation, GenRad Incorporated, Hybrid Systems Corporation, IBM, Keithley Instruments, Incorporated, NCR Corporation, Polaroid Corporation, Raytheon Company, Sanders Associates, Incorporated, Teradyne Incorporated, and United Technologies Corporation.

MICROSYSTEMS TECHNOLOGY LABORATORIES

The Microsystems Technology Laboratories carry out research in the fabrication and study of small monolithic structures and their use for the implementation of interesting integrated systems. These systems span the range from X-ray lenses to VLSI circuits. The people involved include 14 faculty, 20 research staff, 120 graduate students, and 16 technical support staff, with affiliations in the departments of Electrical Engineering and Computer Science, Materials Science and Engineering, Chemical Engineering, and Physics, and other affiliations in the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Electromagnetic and Electronic Systems, the Laboratory for Information and Decision Systems, the Center for Space Research, the Turbulence Research Laboratory, and the Harvard-MIT Division of Health Science and Technology.

The research may be grouped in ten areas: (1) Integrated Circuits, both analog and digital, with the theme of technology-intensive integrated-circuit design. For example, there is considerable activity in high-accuracy A/D converters using novel integrated-circuit technologies. (2) Integrated Sensors, including technologies for micromachining, design of microsensors and microactuators, and the application of these devices to physical and chemical measurements. (3) Power Devices and Circuits, including projects in very high frequency power converters and in the general advancement of power-device performance and novel fabrication procedures for energy-storage devices. (4) Electronic Devices, operating in the semi-classical regime. (5) Quantum Effect Devices, specifically designed to take advantage of quantum mechanical effects arising from ultrasmall device features. (6) Submicron Structures, including some "nanofabrication" projects that are not directly related to electronic devices. The Submicron Structures Laboratory develops techniques for fabricating surface structures with feature sizes in the range of nanometers to micrometers, and uses these structures in a variety of research projects. (7) Fabrication Technology, covering a broad area of processing and device fabrication, with two main themes: novel processes for integrated-circuit and device fabrication in silicon and compound semiconductors, and materials processing. (8) Computer-aided Fabrication, including computer-based modeling and simulation of fabrication processes, and computer-based process design and execution in a realistic fabrication environment. Several components of the latter area of work are already implemented in the Integrated Circuits Lab of MTL. (9) Materials, particularly the growth and characterization of thin films for electronic applications. (10) Packaging, a new and rapidly evolving area that has been spawned from previous extensive research work on polymer films.

As can be seen, the research activity covers a diverse and rich area in microsystems technology. There is a healthy mix of government and industrial research support.

The MTL facilities are supported in part by the members of the MIT Microsystems Industrial Group (MIG).

FACULTY

There were several faculty promotions this year: Associate Professors Dimitri Antoniadis and Cardinal Warde to full professor; Assistant Professors Rodney A. Brooks, David K. Gifford, Shafira Goldwasser, Bruce R. Musicus, Charles G. Sodini, and John N. Tsitsiklis to Associate Professor.

Associate Professor David K. Gifford was named KDD Career Development Associate Professor in Communications Technology for two years in recognition of his development of an architecture for large scale information systems. Associate Professor George C. Verghese was named Carl Richard Soderberg Associate Professor in Power Engineering for two years for his outstanding classroom teaching and his unique approach of merging practical engineering problems with control/system theory.

Joining the faculty this year were William J. Dally, who recently completed a PhD at California Institute of Technology. He was also named IIT Career Development Assistant Professor of Computer Science and Engineering in support of his research in the areas of concurrent computing and VLSI. Marc H. Raibert, now Associate Professor of Computer Science, was formerly Associate Professor at Carnegie Mellon University. Peter Hagelstein, formerly of the Lawrence Livermore National Laboratory, is now Associate Professor of Electrical Engineering and was also named a Vinton Hayes Fellow.
Faculty members received a number of honors and awards this year:

Professor Michael Athans and Associate Professor John N. Tsitsiklis received the Outstanding Paper Award from the IEEE Control Systems Society for their paper, "On the Complexity of Decentralized Decision Making and Detection Problems."

Professor Amar G. Bose and Professor Alan V. Oppenheim were elected to membership in the National Academy of Engineering. Professor Bose was cited for his innovation and leadership in the field of sound reproduction and for excellence in engineering education; Professor Oppenheim was recognized for innovative research, writing of pioneering textbooks and inspired teaching in the field of digital signal processing.

H. Kent Bowen, Professor of Electrical Engineering and Ceramic Engineering and Director of the Manufacturing Systems Engineering and Management Program, was named the 1986 Scientist of the year by R&D Magazine for his significant role in transforming the art of ceramics into a science and for his leadership in developing ways ceramics can be consistently manufactured for industry.

The US Department of Health and Human Services has selected Professor Louis D. Braida as a recipient of a 7-year Javits Neuroscience Investigator Award in recognition of his distinguished record of contributions in communicative sciences.

The National Science Foundation named Assistant Professor William J. Dally and Associate Professor Shafi Goldwasser as recipients of 1987 Presidential Young Investigator Awards. These awards fund research by faculty members near the beginning of their careers and help universities attract promising PhDs who might otherwise pursue non-teaching careers.

The International Center of Photography honored Professor, Emeritus Harold E. "Doc" Edgerton with its Lifetime Achievement Award for his role in laying the foundation for the development of the electronic flash by combining the camera with the stroboscope in 1931.

Hermann A. Haus was named Institute Professor, a high honor reserved for faculty members who have demonstrated exceptional distinction in scholarship, leadership, accomplishment and service. Professor Haus received two other honors as well: he received the 1987 Charles Hard Townes Award from the Optical Society of America for his significant contributions to the understanding of nonlinear waveguide interactions, and he was elected to membership in the National Academy of Sciences.

In recognition of his exceptional and inspirational teaching, Associate Professor Jeffrey H. Lang was a recipient of the Graduate Student Council Award for Teaching.

Professor Albert R. Meyer and Professor Joel Moses, head of the department, were named Fellows of the American Academy of Arts and Sciences.

Professor, Emeritus Claude E. Shannon received the Science Trailblazer Award from the Detroit Science Center in recognition of his pioneering work in information theory.

Arthur C. Smith, Professor of Electrical Engineering and department Graduate Officer, received the Billard Award, which is given for special service of outstanding merit performed for the Institute.

Professor Henry I. Smith was named a Fellow of the IEEE in recognition of his unusual professional distinction in the field of submicron-structures technology.

The Optical Society of America elected Professor Cardinal Warde a Fellow, citing his distinguished service in the advancement of optics.

Jerome B. Wiesner, Institute Professor, Emeritus and former President of MIT, was the 1986 recipient of the Nippon Electric Company's C&C (Computers and Communications) Prize, honoring his contributions to the development of the fields of computer science and media technology.

The department hosted several visiting faculty this year:

Jean-Loup Delcroix, Directeur Général of the Ecole Supérieure d'Electricité in France, spent a one-month appointment as Visiting Professor of Electrical Engineering. He participated in the teaching of a plasma physics course and collaborated with Professor Abraham Bers on the writing of a text on plasma physics.
Peter P. Chen, Donald B. Sinclair Visiting Professor of Computer Science, is the Foster Distinguished Professor of Computer Science at Louisiana State University and Director of LSU's Center for Computer and Information System Research. He conducted research with Assistant Professor Rishiyur S. Nikhil on entity relationship databases and taught a graduate level database course.

Visiting Associate Professor of Electrical Engineering Michael Marcus came from the Federal Communications Commission to teach a course on telecommunications technology and policy.

From the University of Brasilia, Visiting Assistant Professor of Electrical Engineering Henrique S. Malvar taught Introduction to Electronics and conducted research with Professor David Staelin in the area of image processing.

Under the auspices of the National Science Foundation's Visiting Professor Program for Women, Visiting Professor of Electrical Engineering Enid K. Sichel taught and conducted research with Professor David Adler on the electronic properties of hydrogenated amorphous silicon.

Rosemary L. Smith, Donald B. Sinclair Visiting Assistant Professor of Electrical Engineering, came to the department from the Centre Suisse d'Electronique et de Microtechnique in Switzerland. She taught and conducted research in integrated circuit technology with Professor Stephen D. Senturia and Assistant Professor Roger T. Howe.

From the IBM Research Center, Visiting Associate Professor of Electrical Engineering Wen I. Wang taught a subject on compound semiconductor devices using MBE technology and conducted research with Professor Clifton G. Fonstad.

A number of faculty members were away during the year:

Associate Professor Harold Abelson spent spring term on sabbatical conducting research at the University of California, Berkeley. Professor Jack B. Dennis, on leave for the academic year, supervised the operation of Dataflow Technology Corporation. Associate Professor Pierre A. Humblet, on sabbatical for the spring term, explored new research at Eidgenossische Technische Hochschule in Zurich. Assistant Professor Thomas F. Knight was on leave for the academic year investigating and implementing architectures at Symbolics Corporation. Professor Frances F. Lee spent spring term on leave, overseeing Lexicon Corporation. Professor Thomas H. Lee was on leave for the academic year finishing his term as director of the International Institute of Applied Systems Analysis in Austria. Associate Professor Jae S. Lim, on sabbatical for the academic year, finished a textbook on Multidimensional Signal Processing. Associate Professor Richard E. Zippel, on leave for the fall term, conducted research at Symbolics Corporation.


Jack B. Dennis, Professor of Computer Science and Engineering, and Francis F. Lee, Professor of Electrical Engineering, retired from the faculty this year. Each will continue to serve the department as Senior Lecturer.

Associate Professor Bernard C. Levy will join the faculty of the Department of Electrical and Computer Engineering at the University of California, Davis; Associate Professor Richard E. Zippel has accepted a position at Symbolics Corporation, and Associate Professor Victor W. Zue will become Principal Research Scientist in the department.

The department was saddened by the death of Professor David Adler, who was regarded as one of the department's outstanding teachers of undergraduates. Professor Adler had done extensive work on the physics of amorphous semiconductors and on the design of devices using these materials. He was also instrumental in the development and operation of the Concourse Program, a year-long alternative program for MIT freshmen.

Professor, Emeritus Eugene Boehne also passed away this year. In addition to teaching, he also served the department as the director of the VI-A program until his retirement in 1960.

JOEL MOSES
INTRODUCTION

The twelve months ending this July can best be described as a year of breathless progress for the field of Materials Science and Engineering. For many it will be remembered as the year of the high temperature superconductor, in which discovery after discovery unfolded. By July, confidence abounded that there would be real devices and machines that would utilize these new materials, and that these new devices and machines would someday greatly change the way we live. Similar, if less dramatic achievements have been made in other areas including magnetic materials, rapidly solidified materials, structural ceramics, composite materials, and opto-electronic materials. Our faculty and students participate at the forefront of these advances, and a sense of achievement, excitement, and opportunity pervades the Department.

This past academic year has been another excellent one for the Department in its educational and research roles and in development of its funding base. Our undergraduate enrollment averages over 45 per class, reaching an all-time high this academic year. At the graduate level, our enrollment reached a high early last year of 277. Since then we have consciously decreased the number to under 250 due to limitations of space, facilities, and faculty. The resulting increased selectivity of our admissions has resulted in a graduate class of improved quality.

A major achievement of the Department during this past academic year was the successful incorporation into its ranks of five new assistant professors. These are: Professor Michael J. Cima in ceramic processing; Professor Michael F. Rubner in polymer/electronic materials; Professor Andreas Mortensen in composite materials; Professor Nicole Herbots in electronic materials; and Professor Stuart B. Brown in manufacturing/mechanical metallurgy. Professors Cima, Rubner and Herbots hold the title of IBM Assistant Professor; their career development professorships come as a part of the two million dollar IBM Grant received last year. Professor Andreas Mortensen holds the ALCOA Assistant Professorship which was also initiated in our Department last year. We welcome these young people aboard and wish them well in their careers.

The Department of Materials Science and Engineering continues to be an outstandingly strong research department. Figures for research dollar volume for the fiscal year ending June 1987 are not yet available, but the total is expected to be approximately that of the previous year, when volume was approximately $15.5 million, supervised for the most part by individual faculty or by groups of faculty. This research was administered through the Department (50%), the Materials Processing Center (35%), the Energy Laboratory (5%), the Center for Materials Science and Engineering (5%), and other laboratories and centers (5%).

Major research efforts continue in each of the different classes of materials: ceramics, metals, polymers, and electronic materials. One way of categorizing our research activities (without regard to materials classes) is:

Materials Science

\{ Structure and Transformations \\
Structure/Property Relations \\
Structure/Processing Relations \\
Property/Performance Relations \\
Process and Systems Modeling \}

Materials Engineering

A great strength of the Department, and a feature that is unique among academic materials departments is that we have programs underway in all of the above five categories, and in all of the materials classes. Raising adequate research funds has not been a problem for the great majority of our faculty, and from a departmental standpoint, our strategy is to encourage research programs that (1) most strongly enhance our teaching programs, (2) contribute most effectively to national and societal needs, and (3) otherwise most effectively contribute to our long range objectives.

The continued strengthening of the Department and the broadening of its programs have been made possible in large measure by the continued support of industry and the continued interaction of the Department with industry. Twelve of our faculty now hold
named chairs, of which five are endowed and seven are term. The five endowed
chairholders and chairs are: H. Kent Bowen, Ford Professor of Engineering; Merton C.
Flemings, Toyota Professor of Materials Processing; W. David Kingery, Kyocera Professor
of Ceramics; R. Erik Spjut, John Chipman Assistant Professor of Chemical Process
Metallurgy; and Bernhardt J. Wuenach, TDK Professor of Materials Science and
Engineering. The seven term chairholders and chairs for the coming academic year are:
Yet Ming Chiang, Mitsui Assistant Professor; Joel P. Clark, Metcalfe Professor; Ronald
M. Latanision, Shell Distinguished Professor; Andreas Mortensen, ALCOA Assistant
Professor; Michael J. Cima, IBM Assistant Professor; Michael F. Rubner, IBM Assistant
Professor; and Nicole Herbots, IBM Assistant Professor. Professor Clark, with support
of his Metcalfe Professorship will develop and teach a "Context Subject", addressing
the industrial competitiveness of Japan and the United States.

Professor Ioannis V. Yannas, who holds a joint appointment in Mechanical Engineering
and in our department, was this year one of 40 new members elected to the Institute of
Medicine. Dr. Yannas, who teaches and conducts research in the areas of polymers and
biomaterials, is best known for his development of "artificial skin" used in the
treatment of burn victims. This brings to fourteen the number of our faculty and
faculty emeriti who are in one of the National Academies (the remaining thirteen being
in the National Academy of Engineering, the National Academy of Science, or both).
Eleven of our faculty are members of the American Academy of Arts and Sciences. Many
other honors and awards were received by departmental faculty and students, and these
are mentioned in a separate section below. In addition, Marguerite A. Meyer received
the Institute's James N. Murphy Award for "unfailing dedication to students".

I am delighted to report that in less than two years after the initiation of our fund
raising drive for the Nicholas J. Grant Graduate Fellowship we have reached and
surpassed our goal of $300,000. The Fellowship will be offered for the first time in
the fall of 1987. We anticipate that this fellowship will exist in perpetuity, with
enough of the interest being returned to the principal so that it will grow gradually
with inflation over time.

In the fall of 1986 we celebrated Morris Cohen's 75th birthday at the TMS-AIME meeting
in Orlando Florida. We announced at that time our intention to seek for him a birthday
present that befit his position as the pre-eminent academic leader today in the
field of Materials Science and Engineering. Our present was to be the "Morris Cohen
Endowed Professorship of Materials Science and Engineering" for which we would seek a
$1.25-$1.5 million endowment. At the time of the writing of this report we are approaching the
million dollar mark in our fund raising campaign and we have every hope and intention
of being able to announce successful conclusion to the campaign during the celebration

Industrial and individual support of other aspects of the Department's academic and
research programs have also been generous; these include undesignated funds, funds for
scholarships and fellowships, and funds for endowment accounts including the Nicholas
J. Grant Graduate Fellowship. Industrial research for the Department is handled
largely through the Materials Processing Center. This Center, under the able direction
of Professor Ronald M. Latanision, has continued to grow so that its total research
budget during the last academic year was over $7 million, of which 45 percent was from
industry.

I regret to report the passing of Professor Fredrick H. Norton last November at the age
of 90. Professor Norton was internationally renowned for his work in ceramics,
including his delineation of the basic principles from which modern ceramic's science
and processing were to evolve.

As described in last year's annual report, the word "metallurgy" crept into the title
of this Department in 1888, when the Department changed its name from that of "Mining
Engineering" to "Mining and Metallurgy". We count that date as our beginning, and so
we will celebrate the academic year 1987-1988 as the 100th anniversary of our
Department. Plans for the celebration are being developed by an internal committee
under the chairmanship of Morris Cohen, aided by an external alumni committee. We will
have a number of special symposia and lectures during the year and our major
celebration will be during June 1, 2 and 3, including Technology Day on June 3. We
look forward in these days to celebrating joyfully the past achievements and the bright
future of our Department and our field.
THE UNDERGRADUATE PROGRAM

The revision of our "first tier" undergraduate laboratory is now complete. Over $500,000 of new characterization equipment has been installed to permit broadening the laboratory to include materials other than metals, and to provide students with hands-on experience with modern tools for structural and chemical characterization of materials. The laboratory, and development of other undergraduate laboratories was made possible by a $1 million grant from the L.G. Balfour Foundation. On December 10, this characterization laboratory was dedicated "The L.G. Balfour Laboratory" at a ceremony at which President Paul Gray presided. Following some demonstrations in the new facilities and the unveiling, Dr. David C. Hill, class of 1969, Vice President and General Manager of Metglas Products, Allied Corporation, delivered the John Wulff Memorial Lecture on "Order and Chaos in the Field of Materials".

We are now proceeding to upgrade the facilities and content of our "upper tier" laboratories. There are four such laboratories, one in each of the materials classes: electronic materials, ceramics, metals, and polymeric materials. These laboratories emphasize the engineering, especially processing, aspects of materials. Special focus is being placed on our metals engineering laboratory, under supervision of Professor Ronald Ballinger. This laboratory, concerned primarily with metal processing and properties, has been greatly expanded by the aid of two significant grants from the Hewlett-Packard Foundation totaling $300,000. These facilities provide the students with hands on experience in use of computers in the laboratory for data collection, analysis, and presentation. It is expected that these facilities, when fully operational, will be used extensively by others of the "upper tier" laboratories.

I reported here last year that Materials Science and Engineering is an arena of intellectual activity that is a little more than a quarter of a century old. In universities, it grew largely from metallurgy departments. Our Department at MIT was at the forefront of this development. Our faculty led in showing that the concepts and approaches which had proved so fruitful in metallurgy could be broadened to encompass other materials as well. Now, the opportunities and intellectual ferment in our field are attracting great attention of chemists, condensed matter physicists, electrical engineers and others. These individuals are bringing greater intellectual breadth to our field, broadening our horizons, and broadening also the academic concepts we convey to our students. It is always challenging, and sometimes painful, to decide what material can be condensed, what can be made more generic, and what is no longer needed. We established last year a special ad hoc committee to specifically address the content of the departmental core courses. We do not seek, at this time, revolutionary changes in these subjects but we do seek continuing and important changes to make them more generic, to delete material no longer necessary, and to include the important principles of our evolving field of Materials Science and Engineering. Discussions in this area will continue during the coming year within the Undergraduate Committee, now to be under the chairmanship of Professor David Roylance.

Discussions were also held last year within the Undergraduate Committee of "materials-specific" restricted electives. A number of important modifications were made in these subjects. As an example, Professor Harry Tuller, who participated in these discussions, led a group of faculty who instituted major changes in the undergraduate electronic materials sequence.

Our undergraduate enrollment last year averaged over 45 students in each of the sophomore, junior, and senior classes. The student body is, therefore, at an all time high. We rank second among departments in the Institute for the highest percentage of women students. Our percentage is 47 percent, just one point behind the leader, Biology. Approximately 75 percent of our students are now in our IIIB (Coop) program. This program involves over 25 industrial and government laboratories. The summer assignments cover the spectrum of materials, with the largest number of students last year being assigned projects in electronic materials. We aim to achieve a better balance among the materials classes by broadening the number of companies involved in the program.

Members of our Department have been active participants in the Athena Program since its inception. This program is aimed at developing and using computers in new ways in education, primarily undergraduate education. One important way in which computers are used in materials education is in helping students calculate and visualize complicated three dimensional problems; e.g. three dimensional stress-strain relationships, three
dimensional crystal structures, and three dimensional electron energy maps. At present, some eight faculty and research staff members (Ballinger, Balluffi, Bristowe, Johnson, Kalonji, Roylance, Sekely and Wuensch) participate in Athena.

Athena is being used in two required undergraduate subjects, one on mechanics of materials and the other on transport and materials processing. It is also being used in an undergraduate elective subject in polymer engineering, and is expected to be used for the first time next year in an undergraduate subject on structure.

GRADUATE ADMISSIONS AND THE GRADUATE PROGRAM

Our graduate student population as of mid-year was 242, down from 277 students at our all-time high in the fall of 1985. This reduction was accomplished in spite of an increased total number of applicants. In 1985, 61 percent of those submitting final applications were admitted; whereas in 1987, only 34 percent were admitted. The overall quality of our applicants remained high and so, with our increased selectivity, we have achieved a major increase in the quality of our graduate student body.

Nearly 30 percent of our graduate students are women. Last year, 6 of 31 doctoral degrees awarded went to women students. This is an all-time high. International students continue to comprise about 30 percent of the graduate student body. This figure has been constant over more than 20 years. We had no minority applicants during this past year. We have made special mailings to black colleges and universities and have prepared a new recruiting pamphlet to use in further minority recruiting efforts.

The distribution of our students among our six graduate degree programs, as of February 1987 was:

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>Percent of total Graduate Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramics</td>
<td>15%</td>
</tr>
<tr>
<td>Electronic Materials</td>
<td>23%</td>
</tr>
<tr>
<td>Materials Engineering</td>
<td>15%</td>
</tr>
<tr>
<td>Materials Science</td>
<td>12%</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>21%</td>
</tr>
<tr>
<td>Polymers</td>
<td>12%</td>
</tr>
</tbody>
</table>

There is general agreement among Departmental faculty that the time is right to reconsider the direction of our graduate curriculum. Our goal is to modify existing core courses and develop new subjects that will have a "generic" materials science or materials engineering approach, and which could ultimately be incorporated into the "core subject" category of our graduate subjects. New subjects in the areas of mechanical behavior, materials processing, structure of materials, and materials characterization are under consideration. A somewhat different doctoral examination procedure would be expected to emerge from this curriculum development.

The new interdepartmental "Program for Polymer Science and Technology" (PPST) was successfully introduced last fall. Students admitted to the program must also be admitted by one of the participating Departments. Departments which have been involved to the greatest extent so far are our department, Chemical Engineering and Mechanical Engineering. Six students were admitted last year and these have now completed their first year of graduate study. Each was supported by a fellowship which permitted full time course work, at the end of which comprehensive examinations were administered by the Interdepartmental Faculty teaching in the Program. Thereafter each student associates with an individual faculty member to perform the Ph.D. research. Normally this will require an additional 2-3 years during which some continuing course work is also possible; financial support will generally come from research project funds obtained by the individual faculty.

A second group of six students will begin the same process in September 1987. As did their predecessors, these students (and others) will benefit from a number of new subjects which have been developed to comprise a comprehensive and integrated intellectual experience in the polymer area. Professor F.J. McGarry of this department has recently assumed directorship of PPST.

Athena Program, described in greater detail in the section on the Undergraduate Program, is also being used to introduce computers to several graduate subjects. It is being used for statistical thermodynamics calculations, and for phase diagram calculations. It is also used in a macroscopic transport subject to aid in the
solution of complex differential equations and to allow rapid display of the results, and is being used in a materials science subject in the solution of complex wave equations and the graphical display of results.

FACULTY

As mentioned above, five new assistant professors joined our faculty during this academic year. They are: Professors Stuart B. Brown, Michael J. Clima, Nicole Herbots, Andreas Mortensen, and Michael F. Rubner. Professor Thomas W. Eagar was promoted to Full Professor and Professor Carl V. Thompson was promoted to Associate Professor. Professor Ronald G. Ballinger was promoted to Associate Professor. Professor Ballinger holds a joint appointment in the Nuclear Engineering and the Materials Science and Engineering Departments.

Professor Samuel M. Allen received a Marion and Jasper Whiting Foundation Fellowship for study and travel in Japan during his sabbatical there this coming academic year. Professor H. Kent Bowen was appointed "1986 Scientist of the Year" by R & D magazine. Professor Bowen continues to lead in development of an Educational Program in Manufacturing and Processing Systems at MIT.

Professor Yet-Ming Chiang was appointed Mitsui Career Development Professor. Professor Morris Cohen received the New England Award of the Engineering Societies of New England and the Leadership Award of the Metallurgical Society of AIME. He was cited for "A career of leadership in education and research in Materials Science and Engineering; for guiding and defining the field today; and for inspiring those who will be its leaders tomorrow".

Professor Thomas W. Eagar received the Champion H. Mathewson Gold Medal from the Metallurgical Society of AIME, for having given the most significant series of papers in a three year period in Metallurgical Transactions, and for important contributions to the science and practice of welding. He also was appointed Henry Krumb Lecturer of the Society of Mining Engineers of AIME. This involves a series of lectures on two subjects: the future of Materials Engineering and Technology Transfer, and Cooperative Research in Japan. He also received a two year creativity extension award from the National Science Foundation.

Professor John F. Elliott was made honorary member of the Japan Institute of Metals and also received the 1987 Educator Award of the Metallurgical Society, AIME. The award was... "In recognition of outstanding contributions to education in Metallurgical Engineering and Materials Science and Engineering."

Professor Flemings was elected Honorary Member of the Japan Iron and Steel Institute. He continues with Dr. Praveen Chaudhuri to chair a major national study for the National Research Council on Materials Science and Engineering. Professor Nicole Herbots was elected a Scientific Member in the Bohmische Physikalische Gazellschaft for her "imaginative investigation of ion beam epitaxial deposition". Professor Linn W. Hobbs was elected president of the Electron Microscopy Society of America.

Professor Heather N. Lechtman received a Fulbright grant for her research in Chile. Professor Koichi Masubuchi received a special award from the Minister of Foreign Affairs of the government of Japan for outstanding contributions in enhancing international cooperation in his professional field. The presentation ceremony was conducted by Japan's Consul General in Boston.

Professor Kenneth C. Russell was elected a Fellow of the American Society for Metals. Professor Donald R. Sadoway received the MIT Graduate Student Council Teaching Award for "outstanding and dedicated teaching of a graduate level course". He also received the T.B. King Memorial Award, the citation for which reads: "Awarded to the individual who has done the most to enrich the educational experience of undergraduates in the Department of Materials Science and Engineering at MIT." Professor Julian Szekely was Extractive Metallurgy Lecturer for the Metallurgical Society of the AIME. The lecturer is selected for significant accomplishments in the field of non-ferrous extractive metallurgy. Professor Uhlig's former students and colleagues celebrated Professor Uhlig's 80th birthday with him at the 1986 Gordon Conference on Corrosion, held in his honor.

Professor John B. VanderSande received the Gillette Award in May 1987 for "outstanding materials science research." Professor Bernhardt J. Wunsch received the Outstanding Educator Award of the American Ceramic Society. This award recognizes "truly
outstanding work and creativity in teaching, in directing student research or in the
general educational process of ceramic educators". Professor Ioannis V. Yannas was
made a Fellow of the American Institute of Chemists.

STUDENTS

The Student Undergraduate Materials Society had another active year. They conducted
mid and final term subject evaluations, arranged a series of lunch time seminars and
other socials. SUMS officers during the fall semester were: Maria Galiano
(President), Lisa Gassaway (Vice President), Ryoichi Shiono (Treasurer), Sharon
Fletcher (Secretary), Louise Sedlacek (Academic Chair) and Stephen Russell (Social
Committee Chair). New officers, elected in spring 1987 are: Lisa Gassaway
(President), Livia Racz (Vice President), Andreas Judas (Treasurer), Anna Napolitano
(Secretary), Paohua Kuo (Academic Chair), and Elliot Schwartz (Social Committee Chair).

Maria Galiano and Stephen Russell, both seniors, were elected to Phi Beta Kappa. Mr.
Eduardo A. Gomez and Dominic K. Leung shared the "Best Senior Thesis Award". Michael
S. Mendolia received a 1986 ASM Undergraduate Scholarship. H.A. Atwater won the
Outstanding Student Paper Award at the Materials Research Society Meeting, Fall 1986.
Jeri Ann S. Ikeda received MIT's Malcolm G. Kispert Award for female scholar-athlete of
the year, the Straight T Award for exceptional athletic performance, was selected for the
Academic All-American Women's Soccer Team (for the second year in a row), and has
for the third straight year co-captained MIT's Women's Soccer Team.

Newly elected officers of the Graduate Materials Council (GMC) are: Bruce Bishop
(Chairman), Simone Peterson (Vice Chairman), Erik Klier (Social Chair), Mark Gore
(Treasurer and Secretary), Mike Capano (DCGS), Mike Warwick (GSC), Stephen Semken (DCGS
and GSC). The Graduate Materials Council continued its seminars and strong social
program, including monthly socials and a summer picnic. It also continued its
important subject evaluation activities. On behalf of the GMC and the Department,
Simone Peterson undertook a recruitment program for minority graduate students by
sending materials concerning the Department, to the career service offices of 84
historically black colleges. A cover letter accompanied the material, signed jointly
by Simone Peterson, the Chairman of the Graduate Committee, and the Department Head.
Matthew R. Libera won the 1986 Materials Research Society Award. P.S. Searson won the
1987 A.B. Campbell award of NACE and M. Kurkel the Romanoff Award, also of NACE.
Heather Shapiro and Marlene Spears received the John Wulff Award for Excellence in
Teaching.

Through the efforts of the GMC, an MIT Student Chapter of the Materials Research
Society was formed with Mary Manger as President. The aim of the Chapter is to foster
interdisciplinary interactions in the materials field. Among its other activities the
Chapter organized an important practice session to prepare students for presenting
papers at the open MRS meeting.

Fellowship awards for one or more semesters were held during academic year 1986-1987 by
23 students. These were: Renu Agrawal, IBM; Ketayun Barmak, Bell Labs; Peter Bordui,
Philips Labs/MPC; Bruce Carvalho, Exxon; Gregory Dynna, MPC, Kimberley Elcoess, Xerox;
David Eng, IBM; Tamala Fletcher, MPC; Linda Carverick, IBM; Susan Hartfield, GM
Corporation; Richard Higgins, ONR; Alan Heulsman, MPC; Timothy Johnson, Steelmaking
Research; Jenh-Yiih Juang, IBM; Richard Kontra, ONR; Raymond Lam, MMRI; Alan Litsky,
Hertz Foundation; Mary Manger, Ida Green; Joana McKittrick, High Aircraft; Hui Quek,
IBM; Richard Roth, Owens Corning; Ariana Sarabia, Hughes Aircraft; Heather Shapiro,
Hertz Foundation; James Speck, NSF; Kathryn Stockton, Instron; Mark Wolf, Grumman; and
Stanislous Zygmunt, ONR.

FACULTY RESEARCH ACTIVITIES

Professor Samuel M. Allen is bringing to a completion his program on the effects of
solute adsorption on interfacial migration in long-range ordered alloys. He has
obtained especially interesting results in an in-situ study in two-dimensional
specimens, observed using transmission electron microscopy. He is also developing
fundamental data on dislocation recovery resistance relative to the design of
ultrahigh-strength steels. Professor Benjamin L. Averbach has developed a biased-
reference XPS method permitting the determination of the Fermi energy in materials with
wide band gaps.

Professor Robert W. Balluffi continues his internationally respected work on direct
observation of grain boundary phase transitions by transmission electron microscopy,
and on quantitative measurement of x-ray diffraction effects from grain boundaries. Professor Michael B. Bever continues his editorial activities concerned with the economics of engineering materials, recycling and environmental problems.

Professor H. Kent Bowen continues to conduct a major research program in ceramic processing and also to carry the double load leading MIT's Manufacturing and Processing System Program. Professor Yet-Ming Chiang continued his research on grain boundaries in electronic ceramics and how these influence properties. He also initiated work on high temperature ceramic superconducting materials. Professor Michael J. Cima, during his first year on the faculty has developed methods to reduce the amount of residual char from polymeric binders used in ceramic processing, improved powder processing methods for producing high temperature superconducting materials, and undertaken a major new program on synthesis and processing of ceramic superconductors.

Professor Joel P. Clark's materials systems laboratory continues to be successfully received by industry and has expanded its sponsorship base to 29 companies, representing 5 countries. Professor Morris Cohen, in collaboration with Dr. Olson, has demonstrated that remarkable resistance to intergranular embrittlement in ultrahigh-strength steels can be achieved by the gettering of phosphorus under conditions of rapid solidification. He has also continued his work on detailed modelling of martensitic nucleation.

Professor Thomas W. Eagar in his welding research has shown that the life of resistance welding electrodes can be greatly increased by electrical and thermal optimization of the geometry. Work on ceramic/metal braze alloys has identified a new braze alloy system to reduce residual stresses. His research has also produces a new age hardenable sterling silver alloy which is being commercialized. Professor John F. Elliott has employed improved an electrodynamic thermogravimetric apparatus developed with Professor Spjut, to observe the phase changes that can occur when a particle in the size range of 10 to 150 microns is heated to temperatures above 2000°C and subsequently cooled.

Professor Merton C. Flemings continues his research on fundamentals of solidification of highly undercooled metallic alloys, with Dr. Y. Shiohara. He also participates in solidification processing aspects of the metal matrix composites program being conducted under the direction of Dr. J.A. Cornie. Professor Harry C. Gatos has discovered a new form of GaAs which can be converted from semiconducting to semi-insulating by thermal annealing in the vicinity of 800°C. This material provides the possibility of fabricating devices at room temperature while the material is semiconducting and then converting it to semi-insulating for isolation purposes by simple thermal treatment.

Professor Nicolas J. Grant has developed and patented a linear gas atomizer which permits rapid solidification of high velocity, fine liquid metal droplets, and impacts the undercooled or partially solidified droplets against a cooled metallic substrate to produce high density, fine structure, and good properties. Professor Nicole Herbots has established a new technique for room temperature oxide growth on silicon, established a microscopic model for ion beam induced epitaxy. With Professors Thompson and Rudman, she has designed and is in the process of securing equipment to construct a facility combining ion beam deposition (IBD) and molecular beam epitaxy (MBE).

Professor Linn W. Hobbs has continued his work on radiation effects in ceramics, high temperature oxidation/sulfidation of transition metals, precision x-ray diffractometry and electron microscopy of semiconductors, and history of materials. Professor Keith H. Johnson is applying his new theory of superconductivity, developed in 1983, to the recently discovered high temperature superconductors. Professor Gretchen Kalonji undertook work on rapid solidification of high temperature ceramic superconductors, and continued her work on atomistic simulation techniques to study interfacial phenomena.

Professor W. David Kingery has completed a study of defect structure and sintering of silicon carbide, and a study of pre-pottery neolithic plaster production. Professor Ronald M. Latanision, in addition to leading the Materials Processing Center, has undertaken a major research thrust on the transport of gaseous and ionic species through polymers used in the packaging of integrated circuits and in multilevel dielectrics.

Professor Koichi Masubuchi continues his work on thermo-mechanical forming of plates using a high-power laser, on stresses and distortion in weldments, welding in space, and crack sensitivities of new high-strength steels. Professor Andreas Mortensen, in
Professor Robert M. Rose's pilot experiments with sheep on a new bone cement yielded dramatically positive results. Tests were also successful of a vacuum free-fall dielectrophoretic materials separator, in separating various metal powders. Professor David K. Roylance is exploring processing relations in glass matrix composites, dimensional control, extended polymer genus, and relation between processing and morphology of polymer blends.

Professor Michael F. Rubner, in his first year on the faculty, has developed a solid research program in two broad areas: diacetylene containing elastomers, and surface active conducting polymers. In the former program, he has demonstrated that control of solid-state cross-polymerization of polymers containing diacetylene groups is an extremely attractive method for improving the optical and mechanical properties of polymeric materials. In the later program he has demonstrated, for the first time, that it is possible to prepare polymer thin films in which and electrically conductive polymer chain, uniquely oriented parallel to the plane of a substrate is separated by insulating regions of controllable dimensions.

Professor Donald R. Sadoway's academic year was marked by two significant discoveries. The first was that of a method for forming a metal coating on a substrate by electrodeposition from fused salt media. The second was of a class of materials that can be employed as anodes and linings in electrolytic cells producing aluminum. These results are of scientific, technological and potential commercial significance. Professor R. Erik Spjut has further developed his electrodynamic thermogravimetric apparatus, and development of a new technique for measurement of the spectral radiance of a heated aerosol and measured supercooling of iron-nickel alloys as a function of atmosphere.

Professor Harry L. Tuller has established clearly that his recently discovered oxygen ion conductor was in fact an intrinsic fast ion conductor. He has prepared individual, electrically active ZnO interfaces and in collaboration with others in the Crystal Physics & Optical Electronics Laboratory, which he directs, he has grown the largest single crystals in the world, to date, of one of the new high temperature superconducting materials. Professor John B. VanderSande has studied crystal nucleation during the solidification of atomized liquid metal droplets. He has also, with Professor Chiang, Rudman, and Yurek, developed a new technique for producing high temperature superconductors by controlled oxidation of a metal precursor.

Professor August F. Witt has obtained exciting results in his study of magnetic field stabilization during growth of semiconductors. When applying axial fields of up to 30
kg, by means of a superconducting magnet he has found that the dopant segregation in the liquid becomes fully diffusion controlled. Professor Bernhardt J. Wünsch has developed vapor transport procedures for the growth of spherical single-crystals of high-temperature fast-ion conducting solid solution in situ in a neutron spectrometer. He has also conducted detailed crystallographic determinations on the first large single-crystals to be produced of \( \text{La}_2\text{CuO}_4 \), the parent phase of the new high temperature superconducting materials.

Professor Ioannis V. Yannas is beginning to interpret his important finding that certain collagen-glycosaminoglycan (CG) polymers are biologically active. His "Stage 1 artificial skin" has been used on over 160 patients in 10 U.S. hospitals and is still being tested for safety and efficacy prior to FDA approval.

Professor Gregory J. Yurek, working with Professor VanderSande and others, has produced high temperature superconducting oxides with novel microstructures by a unique process involving high temperature oxidation of metallic precursors. The result has received wide publicity and it is hoped that this processing technique will provide superconductors in shapes and with strengths, as well as with superconducting properties, that will make them attractive on a commercial scale.

RESEARCH STAFF

The research staff of the Department of Materials Science and Engineering plays an important role in helping conduct almost all facets of the department's activities except formal classroom teaching, and even here they often contribute effectively on an ad hoc basis. During the last academic year the Department had 50 research staff members among its ranks, in the positions of Senior Research Associate, Principal Research Associate, Research Associate, Post Doctoral Associate, Sponsored Research Staff Member, and Visiting Scientist. An additional 11 research staff members, appointed through the Materials Processing Center, were associated with department faculty. The top two ranks on the research ladder are the positions of Senior Research Associate and Principal Research Associate. These titles are currently held by seven individuals who are either appointed through this Department or through a separate laboratory or center, but whose work strongly focuses in this Department. Senior Research Associates are Drs. John S. Haggerty, Jacek Lagowski, Robert C. O'Handley, and Gregory B. Olson. Principal Research Associates are James a. Cornie, John F. Mandell and Paul D. Bristowe.

Dr. Bristowe's theoretical studies of the microscopic properties of grain boundaries have produced the first completely ab-initio calculation of a boundary in a semiconductor. Other calculations, using empirical interatomic potentials representing metals, have led to the first dynamical simulation of structure multiplicity in grain boundaries and also to the positive identification of localized grain boundary dislocations with associated energy cusps in high-angle fcc twist boundaries.

Dr. Cornie has built and supervises a major activity in metal matrix and ceramics matrix composites which involves a large number of faculty and students from this and other departments. His group has made significant advances in understanding infiltration and solidification behavior in metal matrix performs, has developed means for measuring wettability in particulate/metal systems and is designing and building a major composite processing center including infiltration, semi-solid slurry processing, attrition processing, and a plasma assisted CVD facility for tailoring interfaces.

Dr. Haggerty has made significant progress in modelling both his ceramic powder and thin film laser synthesis processes. Silicon and silicon-carbide powders have been made into consolidated parts exhibiting extremely high strengths. Reaction bonded silicon nitride made from laser synthesized silicon power is 2.5 - 5 times stronger than is normally observed. Using the laser process, he has also made undoped and doped amorphous hydrogenated silicon films and has also successfully made Si\(_3\)N\(_4\) insulating films for the first time from laser heated gases.

Dr. Lagowski, working with Professor Gatos, has discovered a new form of GaAs which can be converted from semiconducting to semi-insulating by thermal annealing in the vicinity of 800°C. He has successfully grown the first bulk GaAs crystals of ultra-high epitaxial quality by liquid phase electroepitaxy and has developed a new intrinsic gettering process in silicon compatible with rapid thermal annealing. Dr. Mandell's most important research advance this year was the refinement of a microdebonding test technique for measuring the in-situ bond strength between fibers and matrix in metal and ceramic matrix composites.
Dr. O'Handley inaugurated his Magnetic Surface Characterization Facility with a major capital equipment grant. This facility includes a high resolution field emission microscope. Operation of this facility was made possible by a consortium of six industrial sponsors. He also continues his work toward the development of magnetic quasicrystals with the production of icosahedral and betaphase Al-Mn-Si particles by atomization.

Dr. Olson continues to lead the NSF sponsored university-industry-government program on high-strength steel technology. The program is making good progress revealing new aspects of multicomponent carbide precipitation in recovery resistant alloy martensites, the microstructural basis of void-softening-induced shear instability in ductile fracture, the electronic origins of intergranular embrittlement, and the heterogeneous nucleation of austenite during intercritical heat treatments.

MERTON C. FLEMINGS
INTRODUCTION AND PERSPECTIVE

The mechanical engineering profession is broadly concerned with energy, motion and materials, and the design, production, and management of systems to meet the needs of society. The profession will have a central role in addressing the challenges of the next decade relating to the supply and efficient utilization of energy, manufacturing and productivity, safe and efficient transportation, defense, enhancement of the environment, and health care and human rehabilitation. Mechanical engineering practice is changing rapidly due to the increasing capabilities of computation, information processing and measurement control technology, the continued development of the fundamental disciplines, the growing ability to synthesize new materials and processes, and an improved understanding of the life sciences and human factors. These rapid changes provide both significant challenges and opportunities to the profession and for the education of future engineers.

Student interest in mechanical engineering continues to be strong. The Department has the second largest undergraduate enrollment at MIT with a total of 450 undergraduates. The increase in graduate enrollment during the last five years has been constrained by the Department and 449 full-time graduate students have enrolled this past year representing a small decrease from last year. The demand for students graduating with SB and SM Degrees has remained strong throughout the last five years. The demand for PhD graduates interested in engineering education, particularly in the manufacturing and design areas, continues to be strong as universities respond to the national educational and research needs in these areas.

This past year special emphasis has continued to be placed upon curriculum development. Continued upgrading of equipment and instrumentation has occurred in the undergraduate manufacturing, measurement and instrumentation, project and materials laboratories. A new curriculum plan has been developed for undergraduate and graduate programs in manufacturing. During the next year the undergraduate core manufacturing subject will be revised and a new graduate core subject in manufacturing will be developed.

Faculty effort in identifying and developing research programs in the past year has been notable, particularly in light of the overall support/cost picture. Total sponsored research has grown in the last year by approximately seven percent to reach a level of $7.4 million. During the last year, small increases have occurred in research related to manufacturing and design, while support for biomedical engineering research has remained relatively constant as has support for energy and environmental areas. Research support from industry has continued to be significant representing approximately 25 percent of the total research administered through the Department.

During the year faculty in the fluid and thermal sciences area have strengthened research programs in computational fluid mechanics and turbulent reacting flows, the thermal-fluid processes controlling growth of electronic materials, energy efficiency in buildings and systems, and biofluid mechanics. Faculty in the mechanics and materials areas have developed research in high performance metals, fibers and polymeric materials, and continued major programs in geomaterials and biomaterials. Faculty in manufacturing, design and control have advanced the capabilities in flexible manufacturing and robotics and extended investigations into basic manufacturing processes. Faculty in the biomedical engineering area have continued to make significant progress in developments related to treatment of cancer patients using ultrasound, development of artificial skin for burn victims and in understanding the biomechanics of joints and limbs as well as basic fluid processes related to diseases of the cardiovascular, pulmonary, and ocular systems.

Effort has continued in the development of the Martin Center for Engineering Design. This facility includes a prototype development laboratory, an interactive classroom, and special seminar rooms for design education and research. Project Athena has provided 16 Digital Equipment Corporation workstations for the Interactive Classroom and four graphic display units have been acquired for use in the computer aided design graduate course. Motorola provided eight sets of microprocessor equipment for the prototype laboratory. These facilities have helped to provide a unique opportunity for design education which incorporates computer-aided engineering techniques from concept generation through prototype development in the design curriculum.
PROGRAMS OF INSTRUCTION

Objectives

The Department instructional programs strive to educate mechanical engineers for leadership roles in professional practice and engineering education, and to provide a broad flexible background for entering related fields such as medicine, law, management, and public policy. Programs emphasize a basic foundation in the engineering sciences combined with a strong design orientation and extensive laboratory experience which couples theory and analysis with the physical world. At both the undergraduate and graduate levels, involvement of students with faculty in research at the forefront of engineering practice--through special projects, the Undergraduate Research Opportunities Program (UROP) and theses--is a hallmark of the Department.

UNDERGRADUATE PROGRAMS

Degree Program and Enrollment

The Department undergraduate program leads to the SB in Mechanical Engineering (Course II), which is accredited by the Accreditation Board for Engineering and Technology (ABET) or the SB without specification (Course II-A), which is non-accredited. Course II-B, the Engineering Internship Program, leads to the SB and SM in Mechanical Engineering with industrial experience as an integral part of the program.

The Department enrollment continued at levels comparable to the past few years. The new sophomore class of 156 included 37 women, 23 percent of the class, and 5 black students. Approximately 20 percent of the class are minorities.

Course II-A provides an alternative to the regular mechanical engineering program and is intended for those students who wish to design a special program coupling such areas as biomedical engineering, management, and energy policy with mechanical engineering. Twelve students were enrolled in II-A. The Department has been heavily involved in the School of Engineering Internship Program since its inception in 1977-78. This past year, 63 students from the Department are members of the Program: 9 graduate students, 28 seniors and 26 juniors. In 1986-87 the Department awarded 141 SB degrees (121 in Mechanical Engineering, 10 without specification and 10 in Course II-B).

Undergraduate Curriculum

The Department Academic Policy Committee has reviewed the content and cohesiveness of the undergraduate curriculum and has broadly defined the evolutionary development of the undergraduate curriculum in three areas - (1) development of an integrated laboratory sequence starting with an introduction to instrumentation and measurement and leading to computer-aided data acquisition and analysis, (2) an increased coupling of manufacturing and design, and (3) a strengthening of the basic disciplinary subjects with improved computational techniques. During the last year the core undergraduate materials subject was revised by Professors Lalit Anand and David Parks. Also a major study of the undergraduate and graduate manufacturing curriculum was performed and a plan formulated for revision of the core undergraduate subject as well as the development of an advanced undergraduate elective subject.

Undergraduate Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: Maggie Urbank, President; William Van Doorne, Vice President; and Jesper Otterbeck, Treasurer; continued to make strong contributions to Department and professional activities with a membership of nearly 139 students. Professor Shahryar Motakef served as the Faculty Advisor.

Black ME is an organization of black students which provides a supportive environment for minorities in the Department. Membership in Black ME has continued strong with nearly 40 students. This past year the organization provided academic support in subject reviews, sponsored corporate presentations and had professional engineers make presentations for its membership. The organization was ably lead by Reginald D. Tucker, President; Robert L. Boone, Vice President; Kendra Ann Williams, Secretary; and Gregory Markham, Treasurer. Professor David Gordon Wilson served as the Faculty Advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued its strong tradition of fostering student-faculty relations and serving the Department through its course and instructor evaluation program. Activities during the year included chapter meetings, classroom evaluations at mid-term and end-of-term, and a spring banquet to honor newly elected members. The organization was lead by: Megan Smith, President; Kenneth S. Kharbanda, Vice President; Christian S. Marx, Secretary; and Heather L. Beck, Treasurer with Professor Derek Rowell acting as Chapter Advisor.
Professor Ming-Kai Tse was Faculty Advisor for the Student Chapter of the Society of Manufacturing Engineers. The chapter officers were: Karim Salame, President; Jack Leifer, Vice President; Barb Hove, Secretary and Karina Fu, Treasurer. The SME sponsored two major seminars, one in automation and one in manufacturing and co-sponsored a meeting of Boston area SME chapters.

Undergraduate Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

The National Science Foundation Incentive for Excellence Scholarship Prize was awarded to Marc C. Filerman and Donn H. McMahon for excellence in academic performance and promise in future contributions to engineering.

Several students were recipients of the Departmental De Florez Award for outstanding ingenuity and creative judgement. Ramzi Rishani, won first prize for his "Anti-Slip System for Vehicles". Second Prize was awarded to James E. Rubesch for his "Hall-Effect Shaft Encoder while Patrick J. Lord and James D. Worden tied for third place--Lord for his "Computer Graphic Display for Human Motion Analysis" and Worden for his "Linear Tracking Robot".

John R. Apgar and Jason K. Jonas won the Departmental AMP award for outstanding performance in project work in the mechanical engineering area.

George Holt III, Robert L. Krawitz, Eric B. Koefoot, Andreas S. Vilarreal, Agnes S. Kim and Joseph M. Vorih won the Departmental Robert L. Hallock Tensile Test Award for excellent machining and heat treating of a tensile test specimen in mechanical engineering.

Stanley B. Kyi, Reginald D. Tucker, Howard Hartenbaum, Mark A. Peters, Eric W. Heatzig, Carsten Hochmuth, Alexandra E. Page, Donna J. Kaiser and Corinna C. Fu won the Departmental Wunsch Foundation Silent Hoist and Crane Company award for outstanding design and fabrication in the mechanical engineering area.

Christopher Linn was one of two students to receive the highest award given to students by the Institute at the 1987 Institute-Wide Awards Convocation. He received the Karl Taylor Compton Prize in recognition of outstanding contributions in promoting high standards of achievement and good citizenship within the MIT community.

Also at the Awards Convocation, Graciella Murguia received the Albert G. Hill Prize, which is presented to seniors who have maintained high academic standards and have made continued contributions to improvements of the quality of life for minorities at MIT.

Michael F. Foley received the Malcolm G. Kispert Award presented to the male senior scholar-athlete of the year while Jeffrey D. Klohr received the Harold J. Pettegrove Award in recognition of outstanding service to intramural athletics.

GRADUATE PROGRAMS

Organization

The graduate program is directed by Professors Ain A. Sonin, graduate policy and registration officer, and Carl R. Peterson, graduate admissions officer.

Degrees

The Department offers the SM degree in Mechanical Engineering, the undesignated SM degree, the degree of Mechanical Engineer, and the doctorate in Mechanical Engineering. The undesignated SM degree allows students to design special interdisciplinary programs as an alternative to the doctoral program for students who wish to emphasize applications and/or design, including economic and social aspects.

Enrollment and Degrees Granted

Graduate enrollment in the fall of 1986 was 449 full-time students. In the fall of 1986 there were 35 women, 6 black, 6 Hispanic, and 31 Asian-American students in the graduate program. In September 1986, 256 new students were admitted from 514 applicants and 117 students registered.

In 1986-87 the Department awarded 140 SM degrees (of which 13 were combined SB/SM degrees), 4 Mechanical Engineer degrees and 39 doctoral degrees.

The Department Faculty voted in April 1987 to institute a joint S.M. degree program with the Woods Hole Oceanographic Institute.
In 1986-87, 89 percent of all graduate students received support from the Department, MIT funds, fellowships, the government or industry. Sixty-nine percent of the graduate students were supported by the Department through research and teaching assistantships.

Graduate Curriculum Development

Three new graduate subjects were introduced by Department faculty to strengthen our programs in materials and manufacturing. Professor Ali Argon developed the subjects Micro Mechanisms of Fracture and Role of Microstructure in Mechanical Behavior. Professors Tse and Ernest Rabinowicz developed the subject Nondestructive Evaluation and Quality Engineering.

A new textbook was published during the past year Robot Analysis and Control written by Haruhiko Asada and Jean-Jacques Slotine and a monograph entitled Advanced Fluid Mechanics Problems was prepared by Ascher H. Shapiro and Professor Sonin.

Graduate Student Awards

Mark C. Johnson received a Department Service Award in recognition of his contributions to graduate teaching. Eric G. Vaaler also received a Department Service Award in recognition of his leadership in guiding undergraduates in independent research projects.

RESEARCH

Support Level and Distribution

The total volume of sponsored research for 1986-87 administered in the Department is $7.4 million, representing a growth of seven percent from the research volume last year. Additional sponsored research of an approximately equal amount is administered through interdepartmental laboratories and centers. The Department sources of research support are derived from a wide spectrum of government agencies and industries. The trend of the last few years of a significant portion of research supported by industry has continued and approximately 25 percent of the research administered through the Department has been from industry.

Several companies and foundations continue to provide grants of unrestricted funds to the Department and funds to support the career development of young faculty. These discretionary funds have been used as seed funds to initiate new research areas, to enhance the development of young faculty careers and to acquire equipment for education and research. Several young faculty were supported this year by the Alcoa Faculty Fellowship, the DuPont Engineering Grant and the Rockwell International Assistant Professor Fellowship. These grants have provided significant assistance in initiating research activities by young faculty and the commitment they represent from industry to education is most encouraging.

Research in the Department varies from very basic, fundamental research to the conception, design, and prototype evaluation of innovative systems to serve the needs of society. Approximately half of the faculty are explicitly involved in basic research and almost every research project in the Department has a component of fundamental research. In research applications the fraction of faculty involved in the four major application areas are: manufacturing, materials and mechanics, 35 percent; energy and environment, 45 percent; biomedical engineering, 22 percent; and systems, including transportation, 18 percent.

Research Accomplishments

Manufacturing, Materials and Mechanics

The major Department activities in manufacturing and processing are associated with the Laboratory for Manufacturing and Productivity (LMP). This interdepartmental laboratory is a focus for research which systematically explores the complex interactions among the many facets of design and production and involves faculty in major program areas of manufacturing automation and robotics, metals processing, polymer processing, flexible materials, and tribology. Significant progress has been made in the robotics area through the research of Professors Neville Hogan, Warren Seering, Slotine, Kamal YouCEF-Toumi and Harry West. Development of direct drive motors for robots by Professor YouCEF-Toumi, techniques for obstacle avoidance through impedance matching of robot characteristics to the environment by Professor Hogan, improved structural elements for robot arms by Professor Seering, robot control algorithms by Professor Slotine and development of braced manipulator techniques by Professor West have all been encouraging. Research in polymer processing has been performed through the MIT-Industrial Polymer Processing Program by Professors Nam Suh in materials development, Timothy G. Gutowski in composite materials, and Tse in nondestructive evaluation. Professor David E. Hardt has continued research to improve welding processes and metal forming processes through direct application of automatic control techniques. Professor Steven Kim has started a research program in axiomatic design for manufacturing using artificial intelligence techniques while Professor George Chryssoulidis has initiated a program in intelligent manufacturing. Professor Eli Sachs has initiated a program in the modeling and
analysis of electronic materials process equipment. The industrial consortium under the direction of Professor Rabinowitz and Dr. Nanaji Saka has been expanded with the addition of several new companies to pursue basic research in tribology related to magnetic recording devices, fuel efficient engines and the mechanisms of friction and wear. The research program in flexible materials developed by Professor Stanley Backer has developed an improved understanding of the behavior of fibrous rope materials.

In the Mechanics and Materials area, research conducted by Professors Argon, Frank A. McClintock, Parks and Anand is seeking to develop a better quantitative understanding of the wide variety of processes involved in the mechanical behavior of materials including inelastic deformation, fracture, and thermo-mechanical coupling effects. Applications of the fundamental analytical techniques and basic experimental studies have been conducted for hot-forming of metals, inelastic response of glassy polymers, development of physically-based models of creep damage, mixed-mode elastic plastic crack propagation and interfacial behavior in metal matrix composites.

**Energy Generation and Conservation**

A number of faculty are directing their research to development of advanced analytical and experimental techniques in energy production and conservation.

Research in the REMERGENCE Laboratory, a laboratory facility developed under the joint auspices of the Mechanical and Civil Departments, has been further developed by Professor Michael P. Cleary in evaluating rock fracture related to oil and gas extraction and by Professor Peterson in research directed to improving mining systems.

In the heat and mass transfer area, Professors Tony Patera and Bora B. Mikic have performed analyses, corroborated by experimental data which indicate substantial augmentation of heat transfer rates may be achieved by modulating unsteady flow in channels.

Research in the Sloan Automotive Laboratory has been undertaken with the support of industrial consortiums to evaluate the uses of ceramic materials in engines and to develop an improved understanding of combustion. This effort involves Professors John B. Heywood, James C. Keck, Wai K. Cheng and Ahmed P. Gholien and is complemented by basic research in lubrication conducted by Dr. David P. Hoult. Fundamental studies related to the characterization of combustion have been extended to consideration of turbulent combustion by Professor Tau-Yi Toong.

Several new research programs have been initiated in the Cryogenics Laboratory under the direction of Professor Joseph L. Smith, Jr. and Dr. Yukikazu Iwasa. Major progress has been made in the development of a prototype superconducting generator and in the development of cooling systems for high performance magnets which have application to medical imaging.

Experimental studies to characterize two-phase gas-liquid flows associated with power systems have been conducted by Professors Peter Griffith with particular application to emergency cooling of nuclear reactors and a new experimental program to understand multicomponent flows has been initiated by Professor Harri Kytomaa.

Research in the area of turbomachinery has been continued by Professor Maher A. El-Masri with emphasis on exploration of new cycles for gas turbine systems. In addition, Professor Wilson has continued research in developing design algorithms for turbomachinery.

Research directed to energy conservation associated with improved heat transfer performance of building insulation materials has shown considerable progress under the direction of Dr. Leon R. Glicksman in a program conducted jointly with the Department of Architecture.

A number of fundamental research studies have been conducted this year. Fundamental research in the quantum mechanic foundations of thermodynamics has been continued by Professors Gian Paolo Beretta and Elias P. Gyftopoulos. Professor James A. Fay has developed basic methods of characterizing the dispersion of gases in the atmosphere with application to acid rain. Research to determine transport of heat and mass transfer across vapor-liquid surfaces in low gravity environments has been initiated by Professor Sonin. Professor Ronald F. Probstein and Patricia Renaud have conducted research in the control of ground water at hazardous waste sites.

**Biomedical Engineering**

In biomedical engineering research, encouraging progress has been made in areas related to human mobility and sensory aids, treatment of tumors via hyperthermia, development of artificial skin and development of an understanding of the fluid mechanics related to the cardiovascular, pulmonary and ocular systems.

In the Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation, Professor Robert Mann directed research that culminated in a telemetered hip endoprosthesis providing the first measurements of pressure in the hip joint ever made in a human. Studies conducted in the laboratory by...
Professor Woodie Flowers have continued the development of a microprocessor-based biofeedback and gait analysis system for obtaining above-knee amputees in the use of prostheses while effort to develop aids for the handicapped has continued by Dr. Michael Rosen. Professor Rowell has started the development of a program in medical image processing.

Research results obtained by Professor Ioannis Yannas in collaboration with Dr. John F. Burke of Massachusetts General Hospital to evaluate a Stage 2 biocompatible artificial skin for severely burned patients have been encouraging. Professor Will Durfee has initiated research in the processing of electromyographic signals for the control of human protheseses.

In the Laboratory for Medical Ultrasonics, Professor Padmakar Lele and his colleagues have continued in the patient evaluation of research in which tumors are treated through controlled hyperthermia using focused ultrasound.

Biomedical research in the fluid mechanics laboratory has shown significant progress in the recent work of Professor Roger B. Kamm in developing a basic understanding of the hydrodynamics of ocular solutions in the eye related to diseases such as glaucoma. Professors Shapiro and Kamm are collaborating on research involving theoretical and analytical studies of the flow in collapsible tubes related to arterial flows. Also, research by Professor Forbes Dewey on identifying the genesis of arteriosclerosis has continued in the experimental quantification of the effects of shear stress on arterial flows.

**Systems Research**

In systems and transportation, research is concentrated in the Man Machine Systems Laboratory, the Computer-Aided Design (CAD) Laboratory, the Vehicle Dynamics Laboratory, and the Machine Dynamics Laboratory.

Professor Thomas B. Sheridan and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of underwater remote manipulation with the establishment of an experimental test capability to evaluate and modify an underwater manipulator in research coordinated with the Woods Hole Oceanographic Institute.

Professor David C. Gossard in the (CAD) laboratory have developed automatic scaling techniques for mechanical assemblies which allow scaling to be performed on the basis of design and prescribed constraints in objective functions. This research is complemented by effort to develop, using expert systems technology, designer-machine interfaces which enhance the iterative design functions.

The activity in the machine dynamics and control area has continued to grow with efforts of Professors Steven Dubowsky, Richard H. Lyon, and Seering. Professors Dubowsky and Seering have continued efforts to develop analytical and experimental techniques for evaluation of high speed machine performance, while Professor Lyon has further developed techniques for analyzing vibration signatures as a diagnostic tool in rotating machine performance with a detailed application study of diesel engine characteristics.

In transportation technology, Professors David N. Wormley and J. Karl Hedrick have initiated research relating to automation in the rail industry and to development of dynamic models for evaluation of vehicle safety performance. Research in the control and dynamic performance of automotive vehicles and in truck/pavement interactions was also conducted by Professor Hedrick.

**FACULTY AND STAFF**

**Size and Composition**

On September 1, 1986 there were 60 active faculty: 29 professors, 19 associate professors (11 with tenure), and 12 assistant professors. Seven faculty are minority group members: a black professor, one woman and five Asians. The teaching, research, and technical staff fluctuates at around 70, more than half of whom are part time people whose principal base is either in another department or outside MIT. Among the staff are two Asians and one Hispanic. Of the seven administrative staff, five are women and of the 39 support staff there is one black woman, one Hispanic and one Asian. The Department has nine hourly staff, including two black men.

**New Faculty and Staff**

Five new faculty have been appointed to the Department during the last year.

Drs. Chryssolouris and Sachs are in the Manufacturing area. Professor Chryssolouris was formerly the Associate Director of the Department's Laboratory of Manufacturing and Productivity prior to his appointment. Professor Sachs has extensive industrial experience in process innovation and, in particular, in manufacturing processes associated with electronic components and systems.
Dr. Kytomaa was appointed as an Assistant Professor of Mechanical Engineering in July joining the Fluid and Thermal Science Division while Dr. West was appointed as an Assistant Professor in the Design Division.

Dr. Renaud joined the Fluid and Thermal Science Division as an Assistant Professor in September.

Notable Accomplishments and Awards

At the 1987 Institute Awards Convocation, the Graduate Student Council awarded Assistant Professor Tse a Teaching Award for "exceptional and inspirational teaching".

Assistant Professor Slotine was named the Henry L. Doherty Professor in Ocean Utilization in a two year appointment to be administered through the MIT Sea Grant Program.

Assistant Professor Youcef-Toumi was one of eleven recipients from MIT to receive a 1987 Presidential Young Investigator Award.

Assistant Professor Renaud received a two year appointment as the Esther and Harold E. Edgerton Assistant Professor.

Assistant Professor West received the Mitsui Career Professorship in Contemporary Technology for a term of two years.

Assistant Professor Kytomaa was named the Atlantic Richfield Career Development Assistant Professorship in Energy Studies for 2 years.

Assistant Professor Durfee was selected to be the second holder of the W. M. Keck Foundation Assistant Professorship in Biomedical Engineering for a two year term.

The 1986-87 Jacob Den Hartog Distinguished Educator Award was presented to William C. Unkel prior to his lecture on "Computer Support for the Academic Laboratory".

Professors Suh and Rabinowicz have been named as Fellows of ASME. Professor Rabinowicz has also been named a Fellow of the American Society of Lubrication Engineers.

Professor Smith was awarded the Longstreth Medal for "contributions to the application of cryogenic techniques to rotating electrical machinery" by the Franklin Institute.

Professor Agron was elected a Fellow of the American Physical Society for fundamental contributions to understanding of plastic deformation of polymer glasses.

Professor Griffith was awarded the Admiral Melville Medal for his paper entitled "Initiation of Water Hammer in Horizontal and Nearly Horizontal Pipes Containing Steam and Subcooled Water". The Medal is awarded for the best paper of the year by the ASME.

Professor Heywood received a Certificate of Recognition from the National Aeronautics and Space Administration for his publications, "Performance Predictive Models of Premixed and Disc Wankel Engines" and "Computer Code for Turbo-Compounded Adiabatic Diesel Engine".

Professor Yannas is one of 40 new members elected to the Institute of Medicine.

The International Symposium on Cooling Technology for Electronic Equipment awarded a Plaque of Recognition to Professors Mikic and Patera in testimony of their leadership and lasting contributions to the field of Numerical Methods for Thermal management. Professors Mikic and Patera were also awarded a Certificate of Merit from the American Institute of Aeronautics and Astronautics for their outstanding technical paper, "Heat Transfer Enhancement in Oscillatory Flow in a Grooved Channel".

Professor Ghoniem was chosen as one of 32 engineering educators to receive the 1987 Ralph R. Teetor Educational Award by the Society of Automotive Engineering.

Dr. Egon Orowan, Professor Emeritus, has been awarded the ACTA Metallurgica Gold Medal for his outstanding contributions to materials science.
Resignations/Retirements

Assistant Professor Beretta and Associate Professor El-Masri have resigned from their positions effective July 1, 1987.

Deaths

Professor Emeritus Carl L. Svenson, an active member of the faculty from 1919 until his retirement in 1962, died in July, 1986 at the age of 89. His teaching and research were in the field of thermodynamics.

Professor Emeritus Brandon G. Rightmire, who was a member of the faculty for 34 years passed away on New Year's Day after a long illness at the age of 75. Professor Rightmire was an expert on friction, wear and lubrication and was respected by his colleagues as an outstanding scholar, experimentalist, engineer and teacher.

DAVID N. WORMLEY
The Nuclear Engineering Department, established in 1958, was a pioneer in the development of university research and education in nuclear engineering. Today, in 1987, the objective of the Department is to provide education in science and engineering relevant to the peaceful applications of nuclear processes. Our research aims to advance the forefront of knowledge and to incorporate this knowledge into educational programs that include consideration of safety, environmental, economic, and societal concerns. Our programs focus around four main themes: Fission; Plasmas and Controlled Fusion; Radiation, including Medical Applications; and Energy Economics and Policy.

ACADEMIC PROGRAM

In September 1986 there were 150 students registered in the nuclear engineering graduate program. Of this number, approximately 30 percent were newly admitted. International students accounted for approximately one-third of the graduate population. Interest in our undergraduate program was sustained at last year’s level. According to Institute statistics, we can expect to welcome eleven students to our sophomore class.

During the past year, six women were among the 52 graduates who completed requirements for advanced degrees. A total of 59 degrees were awarded in the following graduate programs: 20 doctorates, 3 nuclear engineers, 32 master of science, and 4 five-year bachelor of science degrees. In addition to the five-year BS/SM awards, two students were recommended for the bachelor of science degree.

As in the past, the Engineering Internship Program continued to be a valuable educational resource for three students. During the year they interned at EG&G Idaho and Brookhaven National Laboratory.

Curriculum development was considered a high priority item by our faculty and students during the academic year. Professors Otto Harling and Norman Rasmussen reorganized the Department’s basic laboratory course in nuclear measurements. This new subject 22.09/59 Principles of Nuclear Radiation Measurement and Protection was successfully taught for the first time during the spring semester. Also during the spring term, 22.069 Undergraduate Plasma Laboratory and 22.69 Plasma Laboratory were updated to include work on lasers and cryogenics. Professor Ian Hutchinson was the faculty member in charge of these two lab courses.

RESEARCH

During the fiscal year ending June 30, 1986, Departmental faculty supervised a research volume of more than $3 million. This figure includes research funded through the Department, the Biotechnology Process Engineering Center, the Energy Laboratory, the Harvard/MIT Division of Health Sciences and Technology, the Materials Processing Center, the Center for Materials Science and Engineering, the Department of Materials Science and Engineering, the Nuclear Reactor Laboratory (NRL), the Plasma Fusion Center (PFC), the Research Laboratory of Electronics, and the Whitaker College of Health Sciences, Technology and Management.

Research Projects

A major effort of continuing research has been the Nuclear Power Plant Innovation Project. The four principal elements of this study involve: 1) the light water reactor (LWR), 2) the modular high temperature gas reactor (MHTGR), 3) the liquid metal reactor (LMR), and 4) institutional and policy analysis.

Research in the LWR area has focused on plant performance requirements, conceptual design innovation and independent technological advances. Professors Michael Golay, Mujid Kazimi, David Lanning, John Meyer, Elias Gyftopoulos, and Neil Todreas are involved in this study. Included in this work is an investigation of the safety features of the Small Boiling Water Reactor that is currently under conceptual development by General Electric Company. The MHTGR project has concentrated its efforts on safety, investment, and licensing goals, incentives for fuel quality improvement, and investigation of a direct-cycle gas turbine combined with the passively safety MHTGR core. Professors Lanning, Richard Lester, Lawrence Lidsky, and Rasmussen are involved in this research. Professors David Wilson and Warren Rosenow of the Mechanical Engineering Department also participated in the direct cycle gas turbine effort. This MHTGR-GT design concept is a passively safe innovative reactor plant that appears to be presently possible at a reasonable cost with modern technology and a plant efficiency of 45 percent. Under the direction of Professors Michael Driscoll and Andrei Schor, research on decay heat removal by natural convection to ambient air in advanced liquid metal reactor designs has advanced.

231
through progressive improvements in numerical models embodied in a computer program. Professor Lester conducts several investigations involving the institutional and policy analysis portion of the overall project. He is focusing attention on the sources of international variations in industrial performance in nuclear power plant construction and operation. This work focuses on the influence of industrial structure and safety regulatory practices on performance. Over the past year Professor Lester and his students have developed a method for analyzing the effects of learning by doing on power plant operating reliability. Additionally, research in collaboration with the Technical University of Berlin (TUB) on LWR performance has been completed. In September 1986 a workshop was held to present results of the study. A major report entitled "International Comparison of LWR Performance" was issued in February 1987. Faculty involved included Professors Golay, Gyftopoulos, Kent Hansen, Lester, Rasmussen and Visiting Professor Eric Beckjord. Our TUB colleague was Professor Dietmar Winje.

A major project is well underway at the MITR-II, under the direction of Professors Harling and Driscoll, to reduce dose rates and stress corrosion in LWRs through experimental research employing in-pile loops. Significant funding for this work has been obtained from national, regional, and local utility organizations in the US. International interest has been expressed, which may lead to a further expansion of our efforts.

A Department of Energy (DOE)-sponsored study of the applications of modern programming languages, PROLOG in particular, in controlling the unavoidable complexity associated with nuclear reactor Technical Specifications and surveillance requirements has been successful. This work, supervised by Professor Lidsky and Lanning, has resulted in a demonstration computerized Technical Specifications monitor. Presentations have been made to utilities through the Energy Laboratory Workshops and by visits to utility companies. Extensions of the computerized Technical Specifications have been developed to demonstrate the use of PROLOG for computer-based reasoning involving nuclear plant surveillance test tracking and scheduling.

Study in the area of radioactive waste management and disposal continues under Professor Lester's supervision. His research in this area is concerned with the assessment of the risks of geologic disposal of high-level radioactive waste and the development of regulatory policies for waste disposal.

Professor Hansen is the coordinator of a multimillion dollar, multiyear, DOE program involving 12 faculty principal investigators from five engineering school departments. Research areas include: thermal plasmas, fracture mechanics, automated welding, and engineering analysis and design.

In the area of nuclear reactor instrumentation and control, Professors Allan Henry, Lanning and Meyer have been involved in a DOE-sponsored program to extend the non-linear digital control concept by the development of a fast running super nodal code for use in control of large power reactor cores. Their program also includes a project funded by Sandia National Laboratory to study automatic rapid maneuvering of reactor power generation. The NRL is jointly involved in these programs.

In the reactor physics area, Professor Henry and his students have continued their investigation of the various aspects of reactor modeling. Among their accomplishments are the following: a multigroup nodal code intended for the analysis of graphite moderated reactors in RZ geometry has been coded. The QUANDRY nodal code has been translated from the IBM mainframe computer to a microvax. Various one-dimensional and point kinetics models have been derived systematically from the QUANDRY nodal equations, and their accuracy vs QUANDRY has been tested. Methods for solving the point kinetics equations in real time have been developed, and the ideas involved have been applied to the development of an improved reactivity meter.

Under the supervision of Professors Hansen, Henry, Golay and Meyer, research continues on the development of the "parity" analog simulation approach to problems in neutron kinetics, fluid flow, and neutron diffusion. This concept has been successfully applied to neutron kinetics and compressible and incompressible fluid flow.

Study in the area of reactor safety, reliability analysis and risk assessment is conducted by Professors Rasmussen and Nathan Siu. They recently completed an evaluation of various evacuation planning strategies for advanced liquid metal reactors. This work, funded by Rockwell International Corporation, was part of the MIT program on advanced reactor design concepts. They are also continuing a project to determine the impact of PRA on plant aging. Development of a method for requalifying a plant for a defined period beyond its licensed life based upon plant failure rate data is currently underway. This project will be supported by Brookhaven National Laboratory.

Research in the area of post-accident behavior is directed by Professor Mujid Kazimi. As part of the Electric Power Research Institute (EPRI) program on severe LWR accidents, he has expanded his study of the impact of uncertainties of core-concrete interaction on the source term in severe LWR accidents.
Efforts in the area of thermal hydraulics and fluid flow have been continuing by Professors Kazimi, Schor, Golay, Meyer, and Todreas. Topics such as single phase multiple channel behavior under decay heat conditions, flow distribution and heat convection mechanisms in bare and wire-wrapped bundles, analysis of heat transfer and hydraulics of two-phase flow, and advanced computational methods for single and two-phase flows are currently under investigation.

Professor Schor has continued his efforts in the area of advanced power system component modeling. Specifically, the focus of the research has been the development of accurate analytical tools for simulating power plant condensers and high power heat pipes.

In the area of nuclear materials and radiation effects, Professor Ronald Ballinger is continuing to study the effects of environmental and microstructural factors on the cracking susceptibility of Ni-Cr-Fe alloys used in nuclear power systems. Professor Harling is exploring methods of developing improved nuclear structural alloys for the critical fusion reactor first-wall application.

Fusion research, both theoretical and experimental, has continued under the supervision of Professors Jeffrey Freidberg, Hutchinson, Kazimi, Kim Molvig and Thomas Dupree. On the theoretical side, Professor Freidberg is conducting an investigation to provide fundamental insight into the behavior of magnetic confined plasmas. This study will be used as a guideline for the future directions of the magnetic fusion program. The experimental activities in controlled fusion and plasma physics are focused at the PFC. A large part of this effort is in the experimental plasma confinement area, particularly the highly successful Alcator tokamaks, and also including mirror and alternative confinement schemes.

Construction of a new tokamak experiment, Alcator C-MOD has been approved by the DOE. This experiment follows the de-commissioning of Alcator C and in many important physics areas (RF heating, impurity control, cross sectional optimization) serves as a prototype for the Compact Ignition Tokamak Project (CIT). Professor Hutchinson is the leader of the design effort for the poloidal field circuit. The CIT experiment is expected to serve as the "flagship" of the US fusion program over the next decade and should produce the first fully ignited D-T plasma.

Professor Kazimi's interest in the area of fusion safety focuses on the assessment of post accident thermal behavior of various blanket designs, the chemical kinetics of Li fires, and on the tradeoffs involved between D-T fuel cycles and other power plants.

The field of radiation includes studies in applied radiation physics, condensed matter science, and radiological science. A new method of extracting the intermicellar structure factor for strongly interacting ionic micelles using a small angle neutron scattering technique has been developed by Professor Sow-Hsin Chen and his students. He has also been conducting quasielastic light scattering studies of ionic micellar solutions and dense microemulsions. Atomistic simulation studies of problems in materials science and statistical physics are being pursued by Professor Sidney Yip and his research assistants.

Professor Gordon Brownell, the principal faculty member in the area of radiological science, and his research group have designed and built a positron tomograph, PCR-I, that is currently undergoing physical and biological testing. A cylindrical tomograph, PCR-II is currently under development. He is also continuing study on the production of epithermal neutrons and the distribution of boron compounds. A study of automated systems had led to interest in an accelerator using low energy deuterons for isotope production. Two additional faculty are currently being sought for positions in this area.

New Research Projects

Professor Harling has initiated a new project related to inoperable brain cancer. This DOE-sponsored effort utilizes the MITR-II for boron neutron capture therapy. The three-year effort, in partnership with the Tufts New England Medical Center, includes irradiations of 5-10 brain cancer patients in the third year.

In conjunction with the Hanford Engineering Development Labs, Professor Kenneth Russell has started research on irradiation induced spinodal decomposition in Fe-Ni and Fe-Mn Invar-type alloys. These alloys are of great interest in advanced fusion and fission reactors because of their great resistance to void swelling, which is destroyed by spinodal decomposition.
An alloy development program is underway under the direction of Professor Ballinger to develop new high strength, low coefficient of expansion alloys, for use in cryogenic applications related to fusion. Thus far the program has resulted in the development of a new commercial alloy with research continuing toward the development of a second generation version of this alloy.

During the year, Professor Freidberg and his graduate students have initiated several new fusion research projects related to tokamak physics. These include: variational analysis of toroidal equilibrium with the aim of developing fast numerical procedures for feedback control and diagnosis of the axisymmetric motion of tokamak plasmas; development of a fast numerical procedure, based on a non-standard application of Green's Theorem, for the determination of the plasma cross section from magnetic probe data; and investigations of ignition and burn control in the CIT.

Professor Kazimi initiated an investigation of the implications of safety for the development of fusion reactors based on advanced fuel cycles, generally thought to be environmentally more benign but less economic than the D-T fuel cycle.

 STUDENT ACTIVITIES

The MIT Student Chapter of the American Nuclear Society (ANS) continues to be the vital link between the student body and the Nuclear Engineering Department administration and faculty. In addition to planning monthly student/faculty dinner meetings, two departmental steak fries, and a holiday party, the Student Chapter scheduled a weekly departmental seminar series. At each seminar, a speaker was invited to present his/her research in nuclear science and engineering. The ANS also participated in departmental orientation activities and organized intramural teams for sporting events.

Honors and Award

A national ANS Scholarship Award was presented to Scott Haney, a graduate student, at the ANS annual meeting that was held in Dallas, Texas, earlier this month. Scott was selected for this prestigious award in recognition of his outstanding effort and academic achievement.

In late spring, the Department announced its graduate fellowships for academic year 1987-88. Michael Zerkle will hold the Manson Benedict Fellowship and the Theos J. Thompson Memorial Fellowship will go to Bernice Eland.

The Sherman Knapp Scholarship for 1986-87 was held by John Keffer. Paul Keller, an incoming graduate student, has been nominated for the 1987-88 scholarship.

Undergraduate students chosen for special recognition were Brion Fox and Christiana Lui. Brion was awarded The Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Christiana received The Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

During the past year, DOE Fellowships were held by 75 individuals throughout the United States. Of the 14 MIT awards, 13 recipients were graduate students in nuclear engineering. Magnetic Fusion Energy Technology Fellowships were held by Scott Haney, John Massidda, Clinton Petty, and Justin Schwartz. Jim Crotinger received the Magnetic Fusion Energy Science Fellowship. Nuclear Energy and Health Physics Fellowships were awarded to Margarita Crocker and Jerry Martin. Recipients of the Radioactive Waste Management Fellowship were Stephen Boerigter, Tue Nguyen, Scott Simonson, Katherine Yuracko, Patrick Hogan, and William Hollaway.

The National Science Foundation (NSF) supported Terry Turnipseed, a first year graduate, during the academic year. In addition to Terry, NSF continued to support Madeline Woodruff and Kin Cheung. As part of the radiological sciences graduate program, Cheryl Denault, David Kennedy, David Michael, Gregory Moore, and Tien Nguyen received support from the National Institutes of Health.

Additional fellowship holders included Dan Wang, the Schlumberger Fellowship in Radiation Physics; Brian Aviles, a GEM Fellow of the National Consortium for Graduate Degrees for Minorities in Engineering; Robert Kirkwood, an award from TRW; Marie Oshima, a fellowship from the Rotary Foundation; Ken Doremus, a Pickard, Lowe & Garrick (PLG) Fellow; and Andrew Dobrzeniecki, an Abbott, Brewer & Zoepfl (ABZ) Fellowship.

Institute-sponsored awards were presented to two of our graduates. They included Daniel Merzke, a Rockwell International Graduate Fellowship; and Rene Sanchez, an award from the Graduate and Professional Opportunities Program. The McAfee Professorship provided assistance for Vesna Dimitrijevic and Susan Cooper.
In addition to the sources of support mentioned above, over 50 percent of our graduate student body received financial assistance in the form of research and teaching assistantships.

FACULTY ACTIVITIES

During the past year the Nuclear Engineering faculty have participated in various activities, both on- and off-campus. A summary of their accomplishments during this period is presented below.

A special two-week summer course entitled "Nuclear Power Reactor Safety" was presented once again during 1986. Under the direction of Professors Rasmussen and Todreas, this offering attracted members of the US nuclear industry as well as those of the international community. Professor Henry again offered the program "Modern Nodal Methods for Analyzing Light-Water Reactors" during the summer of 1986. This week-long course was well attended and well received.

Faculty involved in the Nuclear Power Plant Innovation Project have participated in seminars and workshops regarding this research. For instance, Professor Lidsky again offered the program "Modern Nodal Methods for Analyzing Light-Water Reactors" during the summer of 1986. This week-long course was well attended and well received.

Departmental administrative positions were handled by the following faculty during the 1986-87 year. Professors Freidberg and Kazimi completed their inaugural year as Graduate Admissions Officer and Graduate Financial Aid Officer, respectively. Professor Driscoll served as Graduate Recruiting Officer. Professor Henry continued to represent the Department on the Committee on Graduate School Policy (CGSP). Professor Meyer, who chaired the Committee on Undergraduate Students, also served as the faculty advisor for the honorary Alpha Nu Sigma Society. Professor Siu was faculty advisor for the ANS Student Chapter. Professor Ballinger continued to supervise the UROP program, the Engineering Internship Program, and served as the Undergraduate Financial Aid Officer. Departmental IAP activities were organized by Professor Schor. The Department's Safety Committee and its Computer Committee were chaired by Professor Todreas.

In addition to Departmental obligations, Nuclear Engineering faculty have actively contributed to both School of Engineering and Institute activities throughout the year. Professor Rasmussen continues to serve as Chairman of the MIT Committee on Reactor Safeguard, and is a member of the PFC Visiting Committee and the Institute Council on Environmental Health and Safety.

Professor Lester was appointed as Executive Director of the MIT Commission on Industrial Productivity, a group of 17 senior faculty members and administrators charged by President Gray with the task of exploring the role of the nation's universities in helping to overcome the problem of weak productivity growth in US industry. He is also a member of the Committee on International Institutional Commitments.

Professor Gyftopoulos continued his services as Faculty Chairman of the MIT Sustaining Fellows Program. He also served as Chairman of the Interschool Working Group on Context Subjects, and was a member of the Killian Faculty Achievement Award Selection Committee for 1987-88.

Besides serving as departmental CGSP representative, Professor Henry holds membership on the Institute's Advisory Committee on Shareholder Responsibility. Professor Lidsky has been selected to chair the Institute Committee on Curricula. Professor Yip is a member of the Committee on Student Affairs.

Also during the year, Professor Brownell participated in the Committee on Radiation Exposure to Human Subjects. Other faculty appointed to Institute committees include Professors Molvig and Golay. Professor Molvig is a member of the Faculty Club Advisory Board, and Professor Golay serves on the Committee on Outside Professional Activities.

Professor Harling directs operation of the interdepartmental Nuclear Reactor Laboratory and is a member of the MIT Committee on Reactor Safeguard. Additional faculty members serving on this committee include Professors Ballinger, Lanning and Kazimi.

Several Nuclear Engineering faculty members were invited to chair and/or present papers at professional meetings during the year. Professor Henry was a member of the Program Committee for the American-European Nuclear Society Topical Meeting on Reactor Physics and Mathematics. He also chaired a session and presented a paper at the meeting held in Paris.
In August 1986, Professor Chen was chairman of the Gordon Conference on "Water and Aqueous Solutions" which has been held every two years for the last 20 years. In February, he was invited to speak at the International Winter School in Les Houches, France.

At the invitation of Professor Kazimi, European and Japanese researchers attended an international workshop on safety aspects of lithium that was held at MIT during the summer. In September, he presented the results of his work on severe accident phenomena at a Specialists' meeting organized by the Center for Studies of Nuclear Installation at EPRI. He was also a US delegate to the workshop on fusion safety research convened by the International Atomic Energy Agency at Culham, England, in November.

Last October, Professor Schor acted as session chairman at the twelfth Liquid Metal Boiling Working Group meeting, which took place in Ispra, Italy.

Professor Hansen was an invited speaker at a forum entitled "Beyond Chernobyl: The Future of Nuclear Power." This on-campus presentation was arranged by MIT's Technology and Culture Seminar.

Professor Harling participated in a National Research Council study of the cost and value of university research reactors. He provided the keynote address at this meeting.

During the past year, Nuclear Engineering faculty have participated in various activities in the professional community. Professor Rasmussen is a member of the National Science Board. He continues as a member of the Scientific Advisory Committee for the Cleanup of TMI-2. He recently chaired the committee on Hydrogen Combustion of the National Research Council. He continues as Chairman of the LNG Safety Committee of Cabot Corporation, and as a member of the Board of Trustees of Northeast Utilities.

Professor Lanning continues to serve on the Safety Audit Committee at Northern States Power Co., the Nuclear Safety Review and Audit Committee at Boston Edison, and the Source Term Review Group for Stone & Webster Engineering Corporation. Professors Lanning and Todreas were appointed by the National Academy of Sciences/National Research Council to serve on the "Committee to Assess Safety and Technical Issues at DOE Reactors." Professor Todreas is chairman of the EG&G TMI-2 Accident Analysis Industry Review Group and he also serves on the B&W utility owner group Independent Advisory Board for the owner's safety performance and improvement program.

Professor Golay is a member of the Atomic Industrial Forum. Professor Hansen continues to serve on the Energy Research Advisory Board Panel on Civilian Nuclear Power, and on the Scientific Advisory Committee to the Idaho National Engineering Laboratory. He was recently selected a member of the National Research Council's Commission on Engineering and Technical Systems.

Professor Russell began service on the Program Advisory Committee of the Los Alamos Meson Production Facility. Besides serving on the advisory committee for the DOE's Magnetic Fusion Technology Fellowship Program, Professor Kazimi is a member of a DOE panel that will assess the economic, safety, and environmental aspects of fusion energy utilization in the next century.

ANS positions are held by Professors Henry, Driscoll, and Schor. Professor Henry is a member of the Program Committee of the Mathematics and Computation Division. Professor Driscoll completed his term (1985-87) as a member of the Executive Committee of the Fuel Cycle and Waste Management Division. He has also been appointed a member of the review committee for the Applied Physics Division at Argonne National Laboratory. Since September 1986, Professor Schor has served as program chairman for the Northeastern Section of the American Nuclear Society.

Two faculty are represented on editorial review boards. They are Professor Todreas on the thermal design section of the Journal of Nuclear Engineering and Design and Professor Henry on Nuclear Science and Engineering.

Honors and Awards

Honors were bestowed upon several faculty during the year. The Outstanding Teacher Award for the academic year 1986-87 was presented to Professor Henry by the MIT Student Chapter of the ANS. Professor Meyer received an Alumni Merit Award from Carnegie Mellon University. Professor Russell was elected a Fellow of the American Society for Metals. Professor Gyftopoulos was named a Fellow of the American Society of Mechanical Engineers. Professor Chen received the US Senior Scientist Award from the Humboldt Foundation in West Germany.
Promotions

Richard Lester was promoted to the rank of associate professor with tenure.

Ron Ballinger was promoted to the rank of associate professor.

Sabbatical Leave

Sidney Yip was on sabbatical leave during the academic year to conduct research in atomistic simulation studies. He was a Visiting Scientist for seven months at Schlumberger-Doll Research. He was also a Visiting Scientist for five weeks each at the Argonne National Laboratory and the University of California, Santa Barbara.

Resignations

During the fall semester, Alan Nelson resigned as assistant professor of nuclear engineering to take up a position at the University of Washington.

Andrei Schor leaves the department this month to join the Charles Stark Draper Laboratory.

SUMMATION

As evidenced by this report, the academic year 1986-87 has been a busy, productive, and satisfying year for faculty, staff, and students. As 1987-88 approaches, we look forward to the opportunities and challenges that it will present.

NEIL E. TODREAS
UNDERGRADUATE EDUCATION

In recent years, the faculty of the Department of Ocean Engineering has redirected its undergraduate education efforts to contribute to a great range of educational and social experiences of MIT undergraduates. Among the less structured activities are the following:

- Assistant Professor Amiram Moshaiov and his wife became faculty dormitory residents this year.
- Professor J. Kim Vandiver is Director of the Experimental Study Group in the School of Science, and he has had a crucial role in a wide range of undergraduate concerns in his position as Associate Chairman of the MIT faculty.
- This year, Professor Justin E. Kerwin offered a unique freshman seminar that provided the first-ever student exposure at this level to computer-aided design. Professor Kerwin will teach the seminar again next year.
- Professors J. Nicholas Newman and Ernst G. Frankel will each offer a freshman seminar next year in a new experimental format in which the faculty member serves as freshman advisor to a group of the students enrolled in the seminar.
- Associate Professor Harilaos N. Psaraftis and Professor J. D. Nyhart (who is appointed jointly in the Ocean Engineering Department and the Sloan School of Management) submitted one of the three successful proposals in the School of Engineering for the development of a "context" subject, intended to help embed undergraduate engineering education at MIT in a broader societal context. They will be developing the new subject next year, in collaboration with Professor Michael Wheeler of the Urban Studies and Planning Department.
- Professor T. Francis Ogilvie has participated for two years in Institute-wide committees that are working to develop programs and options that will help to integrate technical and scientific studies with education in humanities and social sciences. This year, Professor J. Kim Vandiver also served on one of these committees; Professors Ogilvie and Vandiver were the only Engineering faculty on the committee. Professor Jerome H. Milgram was an active participant in one of the committees working under the School's Commission on Engineering Undergraduate Education.
- Ocean Engineering faculty members offer a wide variety of projects under the Undergraduate Research Opportunities Program, which attract students mostly from other departments.

Through such activities, as well as the teaching of undergraduate subjects in other departments, Ocean Engineering faculty members are making greatly increased contributions to undergraduate education at MIT -- contributions that extend far beyond the Department's own student body.

GRADUATE EDUCATION

Naval Construction and Engineering

The Program in Naval Construction and Engineering (Course XIII-A) is offered as a two- or three-year graduate course to prepare students, especially naval officers, to manage and supervise the design of complex naval ship systems. The Program has been offered by MIT since 1901.

Last year, we organized a new, introductory, 20-unit summer subject for incoming students. It includes approximately equal parts fluid mechanics, solid mechanics, and basic naval architecture. In the fall term, it became apparent that the new students were much better prepared for their normal full load of subjects than students had been in previous years, and so we judged the new offering a success. We have just started offering it for the second time, and we expect it to be a permanent part of Course XIII-A. During the year, we undertook some initiatives to improve the integration of thesis research by XIII-A students into both MIT's research programs and design programs of the US Navy and the US Coast Guard.
(i) In September, the Department sponsored the first annual MIT/Navy/Shipyard Cooperative Research Workshop, at which about 20 representatives of USN agencies and several major shipyards presented current problems that require research attention. Twenty faculty members and 50 students attended what were generally considered very useful discussions.

(ii) The Office of Naval Research provided modest funding to support research by XIII-A students, with topics to be determined by MIT after students had submitted proposals. In February, 18 proposals were received from students, out of which six were selected for funding. Actual research started as early as March on some of the projects.

(iii) We started a systematic effort to identify individual potential users of XIII-A research in the Navy and Coast Guard and establish one-on-one contact between them and XIII-A students. Some such liaisons have already proven beneficial, although not all parties have been enthusiastic about the effort.

(iv) We have initiated discussions with USN laboratories to identify problems in their existing research programs that could usefully be studied by students at MIT under the supervision of our faculty. We have received some positive response, although no actions have yet resulted.

Eventually, these initiatives are expected to stimulate fruitful contacts directly between our faculty and researchers and designers in the Navy and the Coast Guard, thus strengthening our overall research program, while improving the relevance of XIII-A theses to service needs.

New and Revised Subjects

Associate Professor Michael S. Triantafyllou is a member of a School-wide faculty group that has developed a new sequence of graduate-level subjects in the broad area of control. Professor Triantafyllou is a key lecturer in one of the fundamental subjects, and he is also teaching a special-purpose follow-on subject on control problems in ocean engineering.

Associate Professor Paul D. Sclavounos offered a new subject in numerical analysis for ocean engineering students. The Ocean Engineering faculty has decided that all candidates for a master's degree must have competence in this area at the level equivalent to this new subject.

Professor Martin A. Abkowitz offered a new subject, Applied Hydrodynamics of Ship Design, filling a gap between the Department's fundamental subjects on marine hydrodynamics and the needs of design-oriented students. We expect that this will be a yearly offering in the future.

BOOKS BY FACULTY MEMBERS

Professor Ernst G. Frankel's new book, "Port Planning and Development," has been published by Wiley InterScience.

Associate Professor Henry S. Marcus's new book, "Marine Transportation Management," has been published by Croom Helm. An instructor's handbook is also available.

Professor Ira Dyer has signed a contract with Cambridge University Press for the publication of a textbook on ocean acoustics. Completion is expected in 1987.

RESEARCH

Ocean Environment Measurement Technology. Professor Arthur B. Baggeroer has been the senior scientist of an ONR project team that conducted a test program this spring north of Prudhoe Bay, Alaska, with three objectives: (1) Development of an autonomous buoy, ARAMP (Arctic Remote Ambient Measurement Platform), which incorporates a low-power IBM-AT computer for recording sensor outputs that provide meteorological data and measurements of water pressure, temperature, and salinity, vector current, ambient acoustics, and ice electrical properties. The buoy also has satellite and aircraft telemetry capabilities for downloading data. (2) Testing of a new 40 km acoustic array. (3) Testing of a multichannel optical disk recording system for acquisition of Arctic data. Professor Ira Dyer also participated in the Arctic tests.

Propulsors. Professor Justin E. Kerwin's work on optimum multi-component propulsors, coupled with a new generation of detailed design and analysis schemes, is making possible substantial improvements in propulsor performance. An example is the non-axisymmetric stator, which, if correctly designed, can both improve efficiency and reduce unsteady blade loading and cavitation.
Forming of High-Strength Steel Plates. Professor Koichi Masubuchi has been pursuing studies on the feasibility of using high-power laser beams (about 7 KW power) to form high-strength steel plates into the complex shapes that are typically required in ship construction. He and his students have demonstrated that such processes are technically feasible. They have developed algorithms to determine optimum heating conditions and patterns for forming plates into prespecified shapes. Novel techniques for measuring distortion have been developed as a means of monitoring the process.

Towing. The towing of ships, barges, and equipment is a complex and often hazardous operation, which is poorly understood in spite of the frequency with which it must be done. Professor Jerome H. Milgram and his students have developed a 12-degree-of-freedom computer model for predicting the motions of a towing vessel and the object being towed. This required that surge motions be predicted, which had not been done before, partly because it is unimportant in most ship-motion problems and partly because surge presents difficulties different from those in other modes of motion. The analysis has been used to estimate extreme towline tensions for a large variety of conditions. A major input to the analysis was a time-domain simulation of cable dynamics, developed by Associate Professor Michael S. Triantafyllou. The results of this research are appearing in user-friendly form in a new edition of the Navy Towing Manual.

Computer-Aided Engineering Design. This is a major new effort that was made possible partly through the Institute's support of the development of the new Ocean Engineering Design Laboratory (reported last year). About two years ago, Professor Chryssostomos Chryssostomidis and Assistant Professor Nicholas M. Patrikalakis identified geometric modeling in the computer as a critical technology that limits the use of all computer-aided design (CAD) systems, especially for the complex design tasks that are typical in ocean engineering. Professor Patrikalakis has made two significant breakthroughs. In the first, he recognized that available CAD systems are weak on algorithms required in the solution of sectioning, set, and offset problems. In the second, he identified the disadvantages of the parametric methods of representation that have been accepted for 20 years and showed that a new formulation based on implicit polynomials promises to solve offset and intersection problems in a mathematically exact and computationally algorithmic manner. Funding has been provided by MIT, General Electric Co., the Sea Grant Program, and the National Science Foundation.

Routing and Scheduling. Among the most difficult problems of transportation routing and scheduling are those that require the prompt and efficient movement of a variety of cargoes from several points of origin to several destinations. Associate Professor Harilaos N. Psaraftis has been studying this problem with support from the Military Sealift Command (MSC). He and his associates have developed a user-friendly program for this purpose, which the MSC has now decided to implement as part of its emergency planning responsibilities. This research, with its practical objectives, has led to new insight on a fundamental theoretical issue, vehicle routing under time-window constraints.

Crashworthiness. Professor Tomasz Wierzbicki has organized a consortium of US and European automobile manufacturers to support a three-year program of research in crashworthiness engineering.

Yacht Racing. Vital to contemporary 12-meter yacht design is the use of a velocity prediction program for computer simulation of a sailing yacht's performance. Such a program and also a special measuring machine for digitizing the shape of a yacht hull were developed in a Department research project some years ago, which had the general objective of providing a more rational basis for handicapping ocean racing yachts. Yachtsmen all over the world are now looking forward to racing under the International Measurement System (IMS), which was developed by the United States Yacht Racing Union with the tools developed at MIT.

FACULTY

Professor Arthur B. Baggeroer has been elected a Fellow of the Acoustical Society of America. He continues to serve as Director of the MIT/WHOI Joint Program.

Professor Robert F. Beck of The University of Michigan was Visiting Professor for the academic year, collaborating with Department faculty in research on free-surface hydrodynamics. Professor Beck has now returned to his home institution.

Dr. Michael J. Buckingham of the Royal Aircraft Establishment (UK) has been Visiting Professor for the past year, working on theoretical problems of ocean acoustics.

Professor Chryssostomos Chryssostomidis continues to serve as Director of the MIT Sea Grant College Program.

Professor Ira Dyer was on sabbatical leave during the fall term, completing a textbook on ocean acoustics. In addition, he has been discharging his duties as President of the Acoustical Society of America.
Professor Ernst G. Frankel was appointed a member of the newly formed Committee on Maritime Research of the Transportation Research Board of the National Research Council. He was awarded the degree Doctor of Business Administration by the Boston University Graduate School of Management, with a thesis, "Management of Technological Change at the Process Level."

Professor Clark Graham, CAPT, USN, resigned to accept another US Navy assignment.

Assistant Professor Dale G. Karr was promoted to Associate Professor. He was also reappointed Doherty Professor of Ocean Utilization for an additional period of two years.

Associate Professor Judith T. Kildow was on sabbatical leave this year, studying marine policy in the maritime industry. She was a guest scholar at Harvard University's Kennedy School of Government.

Professor Koichi Masubuchi received a special award from the Minister of Foreign Affairs of Japan in recognition of his academic achievements and his efforts to strengthen ties between the United States and Japan.

Associate Professor Harilace N. Psaraftis has been named an Associate Editor of Transportation Science, a leading archival journal in the transportation field.

Dr. Henrik Schmidt, a scientist at the NATO Saclant ASW Research Center in La Spezia has accepted an appointment as Associate Professor of Ocean Engineering and will join the faculty in July. Dr. Schmidt has an international reputation for his research on the numerical modeling of acoustic propagation in the ocean. This year, in advance of his appointment, Dr. Schmidt participated in the Department's Arctic experiments north of Prudhoe Bay, Alaska.

Associate Professor Paul D. Sclavoucos presented the keynote address at the First French Colloquium on Ship Hydrodynamics, held at the University of Nantes in February. In March, he presented a special lecture at a Pestkolloquium at Hamburg University honoring Professor Dr. Klaus Eggers on his retirement.

Lt. Cdr. Paul E. Sullivan, USN, was appointed Associate Professor of Naval Construction and Engineering in September 1986. LCDR Sullivan had had extensive experience in the design and construction of submarines and surface ships for the US Navy.

Captain B. F. Tibbitts, USN, was appointed Professor of Naval Construction and Engineering June 1, 1987. He had twice been responsible for the design of all US Navy ships, and he also served as Commander of the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). CAPT Tibbitts replaced Captain Clark Graham, USN, who was named to be Commander of DTNSRDC.

Professor J. Kim Vandiver served as Chairman of the Program Committee for the 1987 Offshore Technology Conference, the leading (and largest) worldwide conference and exposition of this major industry. Professor Vandiver continues to serve as Director of the Experimental Study Group in the School of Science, and he has just completed his two-year term as Associate Chairman of the MIT faculty.

Assistant Professor Dick E. Yue was promoted to Associate Professor. During the year, he was a recipient of a Japanese Government Research Award for Foreign Specialists, and he spent the month of January as a Visiting Scientist at the Ship Research Institute of the Ministry of Transport.

FACILITIES

The Variable-Pressure Water Tunnel was equipped with the latest Laser Doppler Anemometer (LDA), which permits the nonintrusive measurement of velocity fields in experiments. The LDA now has a three-component automated traverse, which greatly improves its usefulness. The laboratory was air-conditioned in the fall.

The new Ocean Engineering Design Laboratory and the Department's Project Athena facility have both become fully operational this year. In the spring, they were connected to the Institute's fiber-optics spine, permitting faculty and students in the Department to access the full range of Athena capabilities for the first time. Regular use of the Athena cluster by Department classes has started.

CONFERENCES

The Department of Ocean Engineering was host in June to a two-day Seminar on 12-Meter Technology, where engineers and researchers who had worked behind the scenes in the recent America's Cup race met to exchange information and plan strategy for the next Cup race. In this field, computational models have achieved great importance, and programs developed in the Department of Ocean Engineering for other marine problems have been adapted to study the aerodynamic and hydrodynamic flows past sailing yachts.
During the spring term, the Department sponsored public lectures by three of the persons responsible for the victory of Stars and Stripes in the recent America's Cup race in Australia, Mr. John Marshall, Dr. Nils Salvesen, and Mr. Charles W. Boppe. (The seminar by Mr. Boppe was sponsored jointly with the the Aeronautics and Astronautics Department.)

Professor Ira Dyer was the Chairman of the Workshop on Structural Acoustics, sponsored by the Office of Naval Research at Woods Hole September 22-25, 1986. The result of the workshop was the identification and description of research directions of potentially high relevance to the US Navy and also of deep intellectual challenge to basic research workers in structural acoustics. Approximately 60 leading professionals in the field of structural acoustics attended the workshop.

ROBERT BRUCE WALLACE ACADEMIC PRIZE AND LECTURE

This year's Robert Bruce Wallace Lecture was presented in conjunction with the MIT Sea Grant College Program Lecture and Seminar Series. A two day workshop entitled Undersea Teleoperators and Intelligent Autonomous Vehicles was held October 22-23, 1986, with the Wallace Lecture as the keynote address. Mr. James R. McFarlane, an alumnus of Course XIII-A, President of International Submarine Engineering, Ltd., spoke on "The Genesis and Metamorphosis of Underwater Work Vehicles."

The Robert Bruce Wallace Academic Prize will not be awarded in 1987.

THE FUTURE OF OCEAN ENGINEERING AT MIT

During the winter and spring, the Department devoted a major effort to consideration of the future of ocean engineering, especially as it relates to MIT. This effort focused on two aspects, (i) MIT's contributions to the US Navy's capabilities in the design of ship systems and (ii) MIT's role in developing potential nonmilitary uses of the oceans.

The first had already received intensive attention last summer and fall, when the Department undertook discussions with the Chief Engineer of the Navy on ways to improve MIT's interactions with the USN design community. The initiatives described above (Graduate Education) in relationship to Course XIII-A were part of this effort. At the request of the Chief Engineer of the Navy, Professors T. Francis Ogilvie and Chryssostomos Chryssostomidis took an active role in the Undersecretary's study of the Navy's handling of research in the hull, mechanical, and electrical aspects of ship-system design. They have continued to participate in a new Navy initiative to develop a strategic planning system for R&D in this area.

In the second part of the effort, during the spring, the Department faculty held weekly meetings to define the major opportunities and challenges in ocean engineering (other than military issues). These eventually focused on the following areas:

- Oceanographic Engineering. Knowledge of the properties and behavior of the oceans can no longer be produced effectively through the traditional means of collecting data by the deployment of research vessels operating on the ocean surface. The field has been revolutionized through the availability of satellite sensors, submersibles, and acoustics, each of which provides an entirely new view of the oceans, but still just a partial view. An entirely new generation of systems is needed for obtaining the data that are crucial to understanding world weather patterns, predicting the availability of life and nutrients in the ocean, and evaluating the availability of as-yet unknown resources in and under the oceans.

- Deepwater Technologies. In the near future, more and more of the world's hydrocarbon supply will come from deepwater sites, but the technology for producing oil and gas at such sites does not exist. The near-term competitiveness of the US energy industry depends on the development of new technology for this purpose. In the longer term, the recovery of mineral and living resources from the ocean will depend on the availability of a range of technologies for designing and operating engineering systems in deep water.

- Arctic Technologies. The Arctic Ocean is both a hostile environment and a fragile one. Major hydrocarbon deposits are believed to exist under the Arctic Ocean. The exploitation of such resources will require the development of entirely new technologies peculiar to this environment.

- Waste Disposal. The oceans have an immense ability to absorb many wastes that result from human activities. Since the 1960s, we have looked on the oceans as a fragile environment, to be protected from all uses as a waste sink, but this concept is now changing. Effective technology and a responsible attitude toward the protection of the oceans should enable us to find solutions to society's needs to dispose of human wastes, radioactive wastes, and hazardous substances on, in, or under the oceans.
In each of the first three areas, the MIT Ocean Engineering Department has unique capabilities to help find solutions. Eventually, some of the same capabilities will contribute to finding ways to use the oceans safely as a means of disposing of the wastes that may otherwise overwhelm us in the near future. We conclude that ocean engineering will be a crucial area of technology for the future, but there are major obstacles at present in persuading government, industry, and the public of the need to invest now in the development of fundamental knowledge and technology for these future needs.

MIT's strengths in ocean engineering are strongly complemented by those of WHOI, and so the Department has proposed that MIT and WHOI establish a joint Center for Ocean Technology, for the purpose of promoting collaboration in research. The administration and staff of WHOI received this proposal enthusiastically. The two institutions working together would constitute the leading center for research in ocean engineering and oceanography in the nation. A joint committee is now developing specific objectives and mechanisms for accomplishing this.

T. FRANCIS OGILVIE
The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. Current research in the Laboratory includes work on robotics, vision, natural language, learning, reasoning and problem solving, deep expert systems, computer-aided programming, supercomputing, and basic theory.

Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky develops general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Professor W. Eric L. Grimson, Professor Ellen Hildreth, Professor Berthold K. P. Horn, Professor Tomaso Poggio, and Professor Shimon Ullman (on leave from the Laboratory) do research in computer vision. Professor Chris Atkeson, Professor Rodney A. Brooks, Professor John M. Hollerbach, Professor Tomás Lozano-Pérez, Professor Marc Raibert, Professor Warren Seering, and Dr. J. Kenneth Salisbury work on other aspects of Robotics. Professor Randall Davis and Dr. Howard E. Shrobe work on deep expert systems that use both functional and physical models. Dr. Charles Rich and Dr. Richard C. Waters explore the creation of intelligent programming environments. Professor Carl E. Hewitt studies distributed problem-solving and parallel computation. Professor William J. Dally is designing the J-Machine for efficient implementation of massively parallel message passing systems. Professor Thomas F. Knight, on leave from the Laboratory, develops the Cross-Omega Connection Machine, a special-purpose machine for concurrently manipulating knowledge stored in semantic nets and image arrays. Professor Gerald J. Sussman, with Professor Harold Abelson of the Laboratory for Computer Science, leads a major new research program aimed, in part, at creating sophisticated problem-solving partners for people working in a variety of science and engineering disciplines.

The Laboratory's 161 members include 18 faculty members, 8 academic staff, 41 research and support staff, and 94 graduate students active in research activities funded by the Defense Advanced Research Projects Agency, System Development Foundation, Office of Naval Research, Air Force Office of Sponsored Research, National Science Foundation, Digital Equipment Corporation, General Motors Research Laboratories, General Electric Company, NATO, Standard Oil Company, Schlumberger, International Business Machines, Martin Marietta, Wang Laboratories, Hughes Research Laboratories, Sperry, Exxon Research and Development Company, NASA, John Deere Foundation, NYNEX, General Dynamics, Lotus, Sandia National Laboratory, Siemens, Olivetti, and Analog Devices.

ROBOTICS

The Laboratory's robotics researchers investigate the principles underlying the intelligent connection of perception to action. Autonomous robots must be able to coordinate perception, reasoning, and action activities to achieve goals in changing, uncertain, and unstructured worlds. Researchers in the Laboratory direct efforts in the following areas: reliable locomotion; model-building; planning in the face of uncertainty; and refined, compliant manipulator control.

Mobile Robots

Professor Brooks, Anita M. Flynn, Jonathan H. Connell, and other members of the Mobile Robotics group investigate methods for building robust control systems for mobile robots that operate autonomously and in real time in changing, unpredictable environments. The group completed their first mobile robot, named Allen, in January, 1986. Off-board LISP machines connected by a television-and-radio link to on-board stereo video cameras and ultrasonic range sensors provide the computational power necessary to control the robot. Allen spends much of his time exploring Laboratory space, avoiding collisions with inanimate objects and with people moving through the environment. Exploring is the precursor phase to map building, where the robot will build maps of its environment by combining many noisy sensor measurements taken over a period of time.

Professor Brooks has defined several levels of behavioral competence that he believes are necessary for a robust mobile robot control system. As a robot becomes more competent, more processor power is added, leaving existing processors
unaware of higher-level control layers. The resulting multi-processor architecture, called a subsumption architecture, is unlike other current multi-processor designs because there is no shared memory or expensive switch, and all processors are completely asynchronous. Peter W. Cudhea is investigating improvements to the subsumption architecture and how it can implement robot control systems with multiple but coordinated goals. Markus Toth has built a prototype compiler which transforms subsumption architecture programs into optimized asynchronous gate-level logic arrays. A final step will convert them to VLSI masks for implementation in silicon.

In order to explore issues of environment interaction as an active participant, the research group finished construction of a second mobile robot, named Herbert, which features a lightweight arm and a 24-processor parallel processor on board. The arm's large workspace enables the robot to pick up objects from both tabletops and floors. Local obstacles are detected by infrared proximity sensors designed by Peter Ning. David Chanen built a compiler for programs written in the subsumption architecture. It carries out static load analysis and automatically partitions the program to run on the onboard parallel processor. Mr. Connell, Mr. Ning, and Grinnell More have designed and started fabrication of a laser light stripe to go onboard the robot. Novel features include special purpose electronics to avoid the need for a frame grabber, and a high speed daisy chain bus which spreads data through parts of the onboard parallel processor for real time object recognition. While construction of the robot was under way Professor Brooks and Mr. Connell used real-time simulators of the robot and its environment to develop methods for wall map building, map following, object recognition and task planning.

Professor Brooks, Ms. Flynn, Mike Ciholas and Mr. More have designed a third robot, named Seymour, to investigate all-passive sensing strategies for mobile robots. The primary sensing will be visual. Professor Brooks, Ms. Flynn and Dr. Thomas Marill have implemented a set of algorithms which use visual flow of edges in images from forward-looking cameras to calibrate a stereo vision system. This alleviates the need for a separate calibration phase in front of a visual test pattern before running the robot, as is routinely used in other research groups. Instead, these algorithms continuously update calibration parameters by observing how unknown objects appear to move in the field of view. This makes the robot tolerant of its unavoidable mechanical drifts over time, and even lets it recover in seconds from severe collisions or other impacts which might cause gross mechanical misalignments of its cameras. Ian Horswill has developed vision algorithms for following corridors using ceiling lights as landmarks. To run all these algorithms on the robot Mr. Ciholas has designed and commenced fabrication of an onboard, low power, high speed, digital signal processing computer to process images from four linear cameras, each at 10 frames per second. It has software control over all aspects of image capture, enabling experiments where the robot operates in environments with uncontrolled lighting.

Much of the fabrication, testing, and design modifications on the three robots have been carried out by undergraduate research assistants, including Wendy Wang, Peggy Chang, Beth Fellingham, Ting Kao, and Hai-Duong Vo.

Ms. Flynn has completed a pilot study on the possibility of fabricating complete autonomous mobile robots from a single piece of silicon. The study looks at recent technology developments in micro motors built from silicon at MIT, Bell Labs and Berkeley; at advances in solar cells in Europe; at the silicon compiler under development by Mr. Toth; and at new integrated circuit based sensors developed at MIT. The report concludes that these technologies all seem to be converging to a point where a single chip robot will be feasible in a few years, although there is still uncertainty on methods for coupling the available motors to locomotion systems. As a precursor to a single chip robot, Ms. Flynn has proposed building a rubber band powered 80mg airplane (such small airplanes have previously been built at the Aeronautics and Astronautics Department at MIT) with a single silicon chip onboard. The chip will include the necessary solar cells for power, a charge-coupled video camera, actuators for yaw and pitch control and processing to support obstacle avoidance.

William Y-P. Lim continues to work on model-based vision. The goal is to develop vision algorithms for selecting naturally occurring objects as landmarks—objects that may be recognized from different viewpoints—to enable mobile robots to build maps of their environments. Central problems include finding the right multi-scale representation, the right scheme for indexing the model database by key features, and suitable matching algorithms. Over the last year he has implemented a constraint-based matcher for natural irregularly shaped objects, which simultaneously matches an input description against all elements of a model library.

Daniel A. Frost completed a comparison of potential field methods for finding obstacle-free paths for a mobile robot with methods based on the calculus of variations. Mr. Frost developed the latter scheme to generate trajectories along paths
which have bounded accelerations and velocities and to ensure that the robot reaches its goal with zero velocity. At the same time a cost function based on closeness of approach to obstacles and duration of the journey is minimized.

**Planning for Collision-Free, Compliant, and Grasping Motions**

Professor Lozano-Pérez and his associates investigate the area of robot motion planning. Their goal is to develop algorithms capable of planning all the detailed robot commands necessary to achieve a task, such as assembly of mechanical parts, given as input the geometric models of the parts and the robot, and a characterization of the robot’s sensing and motion capabilities.

Professor Lozano-Pérez, Dr. Emmanuel Mazer (visiting from LIFIA; France), Joseph L. Jones, and Patrick A. O'Donnell, in collaboration with Dr. Alain Lanusse of ETCA (France) and Dr. Pierre Tournassoud of INRIA (France), have developed and tested the Handey robot system. The Handey system plans all the motions required for pick-and-place tasks involving planar-faced parts. Handey first locates one of the parts on the robot’s work table, then plans where to grasp the part so as to avoid all nearby obstacles. Next Handey plans a collision-free path for the complete robot to reach the part, selects a sequence of regrasping motions (if necessary) to achieve a grasp compatible with the final destination and finally, plans a path to place the part at the specified destination. Handey is currently being extended to encompass planning of guarded compliant motions.

In earlier work, Professor Lozano-Pérez, Professor Matthew T. Mason of Carnegie-Mellon University, and Dr. Russell H. Taylor of IBM developed a method for automatically planning compliant motions. Michael A. Erdmann extended the approach to incorporate a detailed model of frictional interactions among objects. Mr. Erdmann also showed how to separate the issues of attaining a goal from recognizing that the goal has been attained. This approach provides the framework for some recent advances in planning compliant motions.

Steven Buckley implemented and tested a planner capable of constructing sequences of compliant motions for Cartesian robots with three degrees of motion freedom. Mr. Buckley identified a new model for compliant motion planning that combines some of the characteristics of spring-like and damper-like compliances. He then developed a method of predicting the possible outcomes of a sequence of these compliant motion commands in the presence of position uncertainty. This method is used to construct an AND/OR graph representing possible transitions among different contacts between the parts. The planner searches for a sequence of commands that guarantees that the parts move from the initial contact configuration to the specified contact configuration.

Bruce R. Donald has extended the investigation of planning motions in the presence of uncertainty in two new directions. One extension allows uncertainty in the shape as well as position of the objects being manipulated. The idea is to introduce new dimensions in the configuration space of the robot that correspond to variational parameters in the part shape. The other extension allows planning motion strategies that are guaranteed either to achieve the goal or to detect failure when it occurs. Mr. Donald developed a geometrical theory that characterizes the conditions under which such error-detection and recovery strategies are possible. Further, Mr. Donald implemented a planner capable of generating these error-detection-and-recovery strategies for two-dimensional assemblies with several shape variational parameters.

John F. Canny has derived a new algorithm for robot motion planning that is based on the notion of roadmaps, a one-dimensional subset of the robot's free configuration space. This is the first general algorithm for collision-free path planning that runs in single exponential time, with exponent equal to the robot's number of degrees of freedom. This bound is known to be optimal. Earlier general algorithms were doubly exponential in the number of degrees of freedom. The new bound equals or betters the complexity of most special-purpose algorithms that have appeared previously. This bound was obtained using two tools that have not been previously used in computational geometry algorithms: the generalized resultant for a system of polynomials and the notion of stratified sets. Mr. Canny (jointly with Professor John Reif of Duke University) also derived several lower bounds for other motion planning problems: finding the shortest path among polyhedral obstacles (NP-hard), planning with velocity limits (NP-hard), and compliant motion planning with uncertainty (non-deterministic exponential time hard).
Legged Locomotion

Professor Raibert is studying legged locomotion in robots and animals. In previous work at Carnegie-Mellon University, Professor Raibert and his colleagues demonstrated dynamically stable locomotion in machines with one, two, and four legs. Since moving his laboratory to MIT in January, Professor Raibert has explored techniques for control of advanced quadruped running gaits and has demonstrated rudimentary quadruped pacing and bounding; galloping seems to be achievable in the near future. The effectiveness of the techniques and algorithms used for these demonstrations confirm earlier theoretical results.

Jessica Hodgins is exploring techniques for control of stride length during running. Control of stride is an essential ingredient in rough-terrain locomotion, and rough-terrain locomotion is the primary motivation for consideration of legged vehicles. Ms. Hodgins has defined three basic approaches and is evaluating them with experiments on a biped running machine.

Jeff Koechling is studying the factors that limit top running speed in legged systems. He is exploring the relationships among energetics, control, computation, and mechanical structure, and how they may trade off. Last summer Mr. Koechling made a planar biped running machine travel at 11.5 mph, up 3 mph from the previous year.

Professor Raibert and Ms. Hodgins are developing techniques for robot gymnastics. They found that very simple methods can be used to make a biped running machine do a forward flip and a front aerial. The methods rely on prespecified open-loop sequences that can be superimposed on the normal running algorithms. These open-loop sequences are related to an important idea in biological motor control, the motor tape. The work is currently addressing how open-loop sequences can be combined with algorithmic techniques for sensory-based adjustments.

In collaboration with Professor Thomas A. McMahon of Harvard University, Professor Raibert is relating results in running robots to the behavior of running animals. Their experiments on a range of quadrupeds—mice, rats, squirrels, dogs, and horses—will address five sets of questions: Do animals run with symmetry? Does a simple mass-spring model of running and the related Groucho number \( uw_0/g \), predict when a quadruped switches from trotting to galloping? Do quadrupeds coordinate their legs by equalizing the forces the legs exert on the ground? Does a parameter describing distribution of mass in the body, \( j = J/(md^2) \), predict what control mechanism an animal will use to stabilize posture in the sagittal plane? Do animals swing their legs to minimize variations in angular momentum during stance? Each of these experiments is motivated by an algorithm or mechanism at work in a legged robot or model. The experiments are scheduled to begin this summer, and will take place at the Harvard Field Station in Concord, Massachusetts.

Robot and Human Arms and Hands

Professor Hollerbach's research involves two major thrusts: the kinematics, dynamics, and control of human arms and robot manipulators; and the grasping, tactile sensing, and haptics of human hands and multi-fingered robot hands.

The MIT Serial Link Direct Drive Arm, the focus of Professor Hollerbach's manipulator research, is one of the few manipulators in existence able to test advanced control methodologies. Using a dynamically estimated model of the Direct Drive Arm, Dr. Chae An, Professor Atkeson, Mr. John Griffiths, and Professor Hollerbach found that independent-joint proportional-derivative (PD) control, typically used for most robots, is less accurate than controllers using a dynamic model of the robot. Among these latter model-based controllers, they found that a feedforward controller and a computed torque controller were about equally accurate, which is a surprising result.

Dr. An and Professor Hollerbach studied the stability of force control on the Direct Drive Arm. They identified two potential sources of instability; dynamic instability and kinematic instability. Dynamic instability is observed in most force control implementations and occurs during contact with stiff environments. The source of the instability was shown to be the multiplication of the force control gain by the environmental stiffness, leading to a highly underdamped system which is easily driven unstable by noise and unmodeled dynamics. A solution was found that involved open-loop joint torque control for fast, stable response, coupled with a low-pass filtered external force sensing loop for steady-state accuracy.
Kinematic instability is a new finding, and occurs in certain Cartesian-based hybrid position/force control schemes. For revolute manipulators, the inverse kinematics transformation can cause instability if the dynamic model is not included in the control law. Curiously, polar manipulators do not exhibit this instability. If the dynamics are included in the control law, however, as in resolved acceleration force control, impedance control, and the operational space method, the system is always stable. Resolved acceleration force control was implemented on the direct drive arm, and in conjunction with the dynamically stable control loop showed behavior better than previously reported.

Using a Watsmart System, Professor Hollerbach and David J. Bennett have demonstrated automatic kinematic calibration of the direct drive arm. The calibration procedure meets the goal of allowing the robot to calibrate itself with minimal human involvement.

Ki Choon Suh and Professor Hollerbach developed global optimization strategies for redundancy resolution, based on torque optimization. The impetus for global optimization is the inevitable failure of local approaches. Global optimization was shown to always yield viable trajectories superior to those obtained with local redundancy resolution procedures.

A new computational architecture was developed for the Utah/MIT Dexterous Hand by David M. Siegel, Sundar Narasimhan, David Taylor, and Steven Drucker. This architecture incorporates Motorola 68020 microprocessors on a VME bus, under supervision of a Sun 3 computer. Elements of the software include message passing, task scheduling, graphics capabilities, a virtual terminal facility, debugging, and file operations.

Significant improvements have been made to the manufacturability and response properties of a rubber-based capacitance array tactile sensor by Mr. Siegel, Inaki H. Garabieta, Mr. Drucker, and Professor Hollerbach. An automatic tactile testing apparatus was designed and used to exhaustively map out the characteristics of the sensor.

Professor Atkeson, Eric Aboaf, and David Reinkensmeyer explored model-based learning techniques for robots. Robots have been programmed to build internal models of their dynamics, improve trajectory following with practice, and learn to throw a ball more accurately. Mr. Aboaf has focused his research on task level learning and improving task models during practice. Mr. Reinkensmeyer is investigating alternative model representation techniques, including modeling systems that take advantage of massive parallelism. Such systems are now being implemented on the Connection Machine.

Dr. Salisbury’s research is concerned with the design, control, and programming of articulated hands and other mechanisms as a means for increasing robot dexterity and adaptability. Fundamental to his approach is the study of the underlying mechanics of manipulation and sensing. He has developed a comprehensive laboratory environment for experimentation with the Salisbury three-finger hand. This includes extensive control software for commanding finger trajectories under position, force, and stiffness control, as well as analytical software for servo experimentation.

The system is implemented on a three-level hierarchy of computers for exercising command and control over the hand. The lowest level of control uses a dozen microprocessors to servo individual tendon motions. The middle level of control uses a VAX 11/750 computer to coordinate tendon motions, implement force and stiffness control, and provide reflex actions in response to definable conditions. The highest level of control is a LISP-based command environment. This system coordinates the finger movements needed to manipulate objects, and monitors and reacts to events occurring during hand operation.

David Brock is developing three miniaturized six-axis force-sensing fingertips based on earlier designs of the sensor developed by Dr. Salisbury’s group. These unique fingertips gather geometric information about contacts with the environment; for example, probing unknown objects to determine their shape and location. Mr. Brock will use these fingers on the Salisbury hand to gather information about objects prior to and during grasping and manipulation. This will permit object recognition and testing of grasp stabilization algorithms developed within the group. Mr. Brock has completed an analysis and demonstrated a number of examples of controlled slip manipulation. This new class of manipulative hand actions permits motions of objects within the hand to be driven by gravity forces and contact with environmental constraints.

Dr. Salisbury’s group is also developing a high-performance lightweight manipulator for use in force controlled applications. The arm is designed to employ all its surfaces for contacting objects and for imparting forces to them. The links are designed to have a slender aspect ratio to maximize the useful surface area and permit access to objects in constrained
environments. In order to perform successful joint force control two areas of the design have had particular attention paid to them. William Townsend has derived a power loss model of high speed cable transmissions that establishes a quantitative lower bound on the friction losses in the system. The analysis indicates that by using a distal cable reduction mechanism to achieve required torques and by using high speed steel cables to transmit the power to the joints, significant reduction in friction losses and an increase in overall system stiffness can be achieved.

Benjamin Paul has developed a model of torque errors encountered in the operation of brushless DC torque motors. He has used the model to implement feed-forward torque compensation on a number of commercial motors which drastically reduces the normally encountered ripple torques. The combination of a low friction transmission and accurate torque source motor results in the ability to perform stable and effectively "sensorless" force control. A single link test mechanism, designed by Mr. Townsend has been constructed to take advantage of these results. It has demonstrated the expected high degree of force controllability. Brian Eberman has begun to implement an adaptive impedance controller for the link which is expected to demonstrate a wider range of controllable stiffnesses than has been possible previously. In a related effort, David DiPietro, in collaboration with Dr. Salisbury and Dr. Dana Yoerger at Woods Hole Oceanographic Institute, is developing a three-link cable driven manipulator for underwater manipulation on the Jason/Argo project.

Professor Seering and his students are studying uses of computation to improve performance of robot systems. Steven J. Gordon has created a workpiece sensing system which determines from a single video image the location of any feature on a part being held by a robot to an accuracy of 0.1 mm. Using this system, the robot can access a loosely positioned part and can then be informed of the part's exact orientation just as it is to be assembled.

Peter H. Meckl has conceived a control strategy for moving robots precisely at high speeds by structuring model-based feedforward driving functions which dynamically compensate for system response characteristics. The driving functions are synthesized to accomplish desired moves without introducing energy at closed-loop plant resonant frequencies. Neil C. Singer has extended this work to control of very flexible arms. Applying the strategy to a 22 degrees-of-freedom model of the space shuttle arm has yielded up to 50 percent reduction in time required to complete a given move.

Steven D. Eppinger has developed a series of system models to explain the instabilities observed when robots are operated under closed-loop force control. To date, these instabilities have limited the use of force control to laboratory environments. Results of this work suggest that actuator bandwidth limitations and system resonant characteristics, two factors previously considered unimportant, are the dominant sources of the observed instabilities.

Kenneth A. Pasch, Erik Vaaler, and Jose Rivero have been examining problems in implementing automated systems. Mr. Pasch has developed a representation for the problem of scheduling tasks in a factory environment which places the better schedules in a single region of the solution space. This significantly reduces the time required to locate an acceptable schedule. Mr. Vaaler has modeled the problem of part assembly in which many uncertainties are present and is now testing heuristics with which a robot could learn to complete the assembly tasks in the presence of these uncertainties. Mr. Rivero has studied the role of robot compliance during part assembly and has developed a series of specifications for compliance characteristics which maximizes the likelihood that a particular assembly operation will be successful.

Two of Professor Seering's students have been working on ways to use computation in the design of mechanical systems. Allen C. Ward has derived a constraint propagation algorithm which allows a computer to select compatible components for inclusion in a design. The algorithm is capable of transforming a general description of a mechanical design into a detailed description of the components which make up the design. Karl T. Ulrich is pursuing the problem of having a computer create new mechanical designs which will perform specified functions. He has completed a program which accepts a set of functional requirements for a mechanical fastener and produces a design for a fastener which meets these requirements.

Redundant Kinematic Chains

Industrial robot arms typically have six degrees of freedom in order to be able to reach an arbitrary point within their work space with an arbitrary orientation of the terminal device or gripper. The transformation from joint angles to Cartesian coordinates has singularities at the boundaries of the workspace that lead to undesirably high joint angle rates. This phenomenon is essentially the same as that of gimbal lock in a three-axis gyroscopic platform (something Apollo astronauts were concerned about). In the case of the gyroscopic suspension, singularities can be avoided by adding a
fourth axis (as is done in missiles that do not use strap-down accelerometers). Once the additional degree of freedom has been added, however, an infinite number of settings of the four axes will place the platform in the same orientation. Some active control method is required to make sure that the new arrangement does not come close to the singularities of the redundant suspension.

A similar thing happens when a seventh degree of freedom is added to an industrial robot arm. A kinematic chain with more joints than degrees of freedom of the terminal device is considered to be redundant. Past methods for solving the inverse kinematic problem (joint angles form Cartesian coordinates) were incremental and hence not nonrepeatable. That is, there was no guarantee that the same arm configuration would be used every time to reach a certain place in the work-space. One effect of this nonrepeatability is uncertainty about obstacle avoidance occasioned by the apparently non-deterministic behavior. Pyung Chang and Professor Horn have developed a fixed transformation from Cartesian coordinates to joint angles that avoids these and other related problems.

In the process Mr. Chang also developed a new performance measure that tells how far the kinematic chain is from a singularity. He demonstrated that previously used performance measures, namely manipulability and condition number, allowed the arm to change configurations without penalty (thus passing right through a singularity). The new measure, product of minors of the Jacobian matrix, assures that the arm solution always remains in the same configuration. The new performance measure will be used in other ways also; for example, in the design of industrial robot arms.

VISION

We have previously described our work in regularization theory—a theoretical framework that unifies several solutions to early vision problems and is based on their ill-posed nature. Our work on developing and applying the theory has continued. We have also done further work in the use of texture information and in developing stereo and motion algorithms. We are also pursuing research in the area of integration of vision sources, learning and parallel algorithms and architectures.

Early Vision

Early vision includes problems such as the recovery of motion and optical flow, shape from shading, surface interpolation and edge detection. These are inverse problems, which are often ill-posed or ill-conditioned. Professor Mario Bertero, Dr. Vincent Torre (both from the Universita di Genova; Italy), and Professor Poggio have developed formal aspects of regularization theory in the linear and non-linear case and analyzed topics in early vision and their ill-posedness, characterizing existence and uniqueness of solutions.

Davi Geiger and Professor Poggio have considered the problem of finding the optimal regularization parameter \( \lambda \)—corresponding to the optimal resolution of the filter—in the case of edge detection. They derive a formula relating the signal-to-noise ratio to the parameter \( \lambda \) from regularization analysis. An implementation of their scheme has been shown to work on natural images and even to explain several perceptual phenomena.

Texture provides a cue for image segmentation, since texture boundaries are often due to surface discontinuities. Harry Voorhees and Professor Poggio have developed a token-based method for detecting texture boundaries in images of natural scenes. In this theory, texture is represented by small-scale intensity features, such as elongated blobs, that represent a simple subset of Julesz's "textons." Texture boundaries are identified where there are sharp differences in the attributes of textons, such as density, size and orientation. They have developed and implemented a scheme to extract blobs as texture tokens from natural images; potential texture boundaries are identified by detecting discontinuities over first-order statistics of attributes in neighborhoods of textons.

Dr. Alessandro Verri (Università di Genova) and Professor Poggio have shown that optical flow, the two-dimensional (2-D) field associated with the variation of the image brightness pattern, and 2-D motion field, the projection of the three-dimensional (3-D) velocity field of a moving scene, are in general quantitatively different. The optical flow, therefore, is ill-suited for computing structure from motion and for reconstructing the 3-D velocity field, problems that require an accurate estimate of the 2-D motion field. As a consequence, they argue that the optical flow should be used to yield information of a more qualitative type. The optical flow is very useful, for instance, for computing an initial estimate of motion discontinuities. Other qualitative properties of the 2-D motion field can give useful information about the
3-D velocity field and the 3-D structure of the scene. They show how the (smoothed) optical flow and 2-D motion field, interpreted as vector fields tangent to flows of planar dynamical systems, may have the same qualitative properties from the point of view of the theory of structural stability of dynamical systems.

It is important to learn algorithms in vision from examples and even more important to adapt and improve them during a learning process. We are now beginning to attack the general problem of learning in early vision. Professor Poggio and Anya Hurlbert have shown that standard regularization algorithms can be learned from a set of examples using classical linear estimation techniques. They have shown that a parallel color algorithm capable of separating illumination from reflectance in a Mondrian world can be learned from a set of examples. The learned algorithm is equivalent to filtering the image data—in which reflectance and illumination are intermixed—through a center-surround receptive field in individual chromatic channels, resembling the retinex color algorithm recently proposed by Land. Their result illustrates that the natural constraints needed to solve a problem in inverse optics can be extracted directly from a sufficient set of input data and the corresponding solutions.

The Vision Machine: Integration and Parallelism

Biological vision systems achieve their high degree of efficiency, robustness and reliability through integration of many visual sources. The simple task of locating object boundaries can be performed far more effectively by integrating evidence of discontinuities in intensity, disparity, motion, and texture than by using evidence from any single visual source. Edward Gamble and Professor Poggio have studied the general integration problem, with the goal of deriving an accurate, robust and explicit representation of the structure of the environment and its surface properties, through fusion of early vision algorithms. They have used Markov Random Fields (MRFs) to integrate vision modules: an MRF on a lattice is associated with each physical process to be integrated and another (binary) MRF with its discontinuities. The lattices are coupled to reflect the interdependence of processes in image formation. In particular they have demonstrated that intensity edges can be usefully combined with sparse depth data to recover more reliable depth discontinuities.

Parallel Algorithms

The Connection Machine is a fine-grained parallel supercomputer originally conceived at the Artificial Intelligence Laboratory, then developed and produced by Thinking Machines Corporation for research in artificial intelligence. The full prototype contains 65,536 1-bit serial processors capable of communicating with each other by means of two distinct mechanisms (the version at the Laboratory has 16,384 1-bit processors). One mechanism has the topology of a Boolean 16-cube and is called the router network, or simply “the router.” The other mechanism is a two-dimensional four-connected x-y grid called the north-east-west-south connections, or “NEWS.” Short-range communication between processors is very efficient using NEWS. Long-range communication is very efficient using the router. Therefore, NEWS is used for operations requiring fast local communication, such as convolutions and relaxation algorithms. The router is used for global operations such as permutation, sorting, merging, summing, histogramming, region-growing, and image sampling.

Dr. James Little, Dr. Heinrich Bülthoff, and Professor Poggio have developed a new, parallel algorithm for computing optical flow. The algorithm is based on a new regularization method that we call “constraint method,” which enforces local constraints and leads to efficient, parallel algorithms. The specific constraint exploited by the algorithm corresponds, in its most general form, to 3-D rigid motion of planar surfaces. Segmentation of the motion field can be obtained from the optical flow field generated by the algorithm. An iterative scheme provides fast, approximate solutions and refines them subsequently. The algorithm has been implemented on the Connection Machine and demonstrated in real-time processing tasks as part of the Vision Machine system.

As an integration testbed of much of the vision effort we are using a system, the The Vision Machine, based on a Symbolics 3640 connected to the Connection Machine. The MIT two-camera stereo system (the equivalent of an eye-head system) is the input device of the machine. Recent work by Dr. Little, Todd Cass, Michael Villalba, Dr. Bülthoff, Mr. Gamble, and Michael Drumheller has made it possible to use the system to “look around,” grab images, compute Canny’s edges, estimate optical flow, derive stereo depth and integrate intensity data with depth in close to real time. In the near future we plan to implement and integrate other early vision modules on the system.

In a related effort we are developing parallel versions of our algorithms on the Connection Machine and testing their performance. Our work develops a new model of computation, a different way of thinking how to solve various vision
problems. Dr. Little, Guy Blelloch and Mr. Cass have devised several schemes for using the communication network of the Connection Machine to implement vision algorithms efficiently. Their analysis shows that different stages of early and middle vision require radically different communication patterns for efficient implementation. We have implemented a range of vision utilities: convolution, edge detection, optical flow, motion discontinuities, stereo, MRF-based integration, learning, and visual routines on our Connection Machine. Several of these schemes (in particular, stereo and motion) use computationally intensive methods which lead to robust performance, but which were not possible with conventional, serial computers.

Rapid judgements about the properties and spatial relations of objects are the crux of visually guided interaction with the world. Vision begins, however, with essentially pointwise representations of the scene, such as arrays of pixels or small edge fragments. For adequate time-performance, the processes that extract meaningful entities from the pointwise representations must exploit parallelism. James Mahoney, in his thesis on image chunking, has developed a framework for fast extraction of scene entities based on a simple, local model of parallel computation. An image chunk is a subset of an image that can act as a unit in the course of spatial analysis, in operations such as boundary tracing, area coloring, and selection of locations for detailed analysis. A parallel preprocessing stage constructs a variety of simple chunks uniformly over the visual array. Subsequent serial processes locate relevant scene components and assemble detailed descriptions of them.

Stereo Vision

The problem of stereo vision continues to be an area of active interest for Professor Grimson and his students. Professor Grimson, in part with David J. Braunegg, has continued the development of the Marr-Poggio-Grimson stereo system, exploring new methods for matching stereo pairs, and examining applications of the method to particular tasks in robotics.

Michael A. Gennert has developed a new computational framework for understanding the problem of stereo vision. Together with a model of the brightness transformation between images taken at different times or from different places, Mr. Gennert has used this framework to develop a new method of brightness-based image matching. This method has been applied to stereopsis, and, with Dr. Shahriar Negahdaripour, to the problem of optical flow. Mr. Gennert has been investigating the implementation of his algorithms on the Connection Machine.

A further step in deepening our understanding of stereo vision involves integrating other visual cues with the stereo process. Based on earlier work by Professor Grimson, Richard P. Wildes has completed the development of a technique for constructing dense surface representations that applies a modified version of a shape-from-shading algorithm developed by Professor Horn and Dr. Michael Brooks to both reflectance and stereo data.

Long-term autonomy for mobile robots presents problems which are different from those encountered with the more limited mission-level autonomy of typical mobile robot systems. Mr. Braunegg is investigating the problem of building and maintaining a world model representation to support the navigation of long-term autonomous mobile robots. This research is investigating the use of stereo vision to enable path and navigation-planning to be performed, as well as developing a method for recognizing world locations based on stereo data.

Recognition

Professors Grimson and Lozano-Pérez have been exploring the problem of interpreting sensory information about the structure of an environment, especially the problem of recognizing objects using models of known objects and information about the position and surface orientation of sensory data points. They have been developing a system that determines both an object’s identity and pose (position and orientation), despite considerable object overlap. Research has continued along a number of fronts.

Professor Grimson has extended the original recognition system in a number of dimensions. Initially, the system assumed rigid polyhedral object models. The system has been extended to recognize simply curved as well as polygonal models in two-dimensional data. A second extension allows the system to recognize parameterized objects, including objects with variable scaling factors; objects with rotating subparts, such as a pair of scissors; and objects that undergo stretching transformations. In three dimensions, the system has been extended to deal with simply curved objects, such as cylinders, as well as rigid polyhedral objects.
The recognition framework has been successfully applied to a number of different sensing modalities including visual cameras, laser range finders, tactile sensors, and sonar range finders. In other applications, Professor Grimson has used the system, in simulation, to determine the position of an underwater vehicle by matching pressure measurements or sonar returns to bathymetric maps of underwater terrain.

A number of other aspects of object recognition have been explored by Professor Grimson’s students.

Daniel P. Huttenlocher is implementing a system for recognizing objects with three-dimensional positional uncertainty, given a single two-dimensional view. The system uses local groups of edge fragments to identify features for recognition, each of which hypothesizes a set of possible objects, and their position and orientation, using a three-point alignment computation that determines position, orientation, and scale of an object in space (under orthographic projection). A verification stage finds objects that are consistent with more than one feature, and uses these to extract additional consistent image information.

David T. Clemens has been investigating methods to extract elementary patches from natural scenes. The goal is to examine different cues that can be detected directly from the image without reference to object models, and use these to hypothesize areas of the image which are likely to come from a single object in the world. Later stages can then efficiently process the patches as units, rather than working only with pixels or edges.

In related work, David Jacobs is investigating the recognition of objects when one has access to a database of many modeled objects. This is done with the help of an initial grouping phase which determines which features in an image are likely to have been produced by a single object. This grouping phase dramatically reduces the combinatorics of recognition by allowing earlier recognition systems to focus on limited subsets of sensory data.

Gil J. Ettinger developed a model-based vision system that exploits hierarchies of both object structure and object scale. The focus of the research was to use these hierarchies to achieve robust recognition based on effective organization and indexing schemes for model libraries. The system can recognize parameterized instances of non-rigid model objects contained in a large knowledge base despite the presence of noise and occlusion, by using an object shape representation that incorporates a component sub-part hierarchy and a scale hierarchy.

Shape Representation

Eric Saund is working on pictorial-based representations for shape intended to support later visual tasks such as shape recognition, and reasoning about the similarities and differences between shapes. The approach builds a rich knowledge base of shape descriptors by extracting primitive features across multiple scales, then grouping them into successively more abstract spatial assertions as known configurations of features are recognized by elements of the shape knowledge base. Among the pattern matching techniques used is dimensionality-reduction; a technique well suited to representing classes of configurations characterized by deformation processes, which commonly occur in shape domains.

Closed Form Solution of Absolute Orientation

One problem that often arises when trying to construct an integrated robotics system is to relate the coordinate systems of the sensors to those of the effectors. One approach is to try minimizing the sum of squares of the errors by suitable choice of the translation, rotation and scaling. This requires that a minimum of three points be measured in each coordinate system. The coordinate transformation is then developed using iterative methods of either a numerical or analog type. But this method requires a good first guess of the transformation and does not lead to the insight provided by a closed-form symbolic solution.

A year ago Professor Horn developed a direct (non-iterative) method for recovering the transformation that both guarantees uniqueness and that does not need an inspired initial guess. If the rotation is expressed in terms of unit quaternions, the desired rotation turns out to be the eigenvector of a symmetric $4 \times 4$ matrix corresponding to the largest eigenvalue. The terms of the matrix are moments computed from sums of products of coordinate components.

This year, with the assistance of Dr. Negahdaripour and Professor Hugh M. Hilden of the University of Hawaii, Professor Horn developed a closed form solution depending entirely on the manipulation of $3 \times 3$ matrices. While somewhat less
elegant than the solution using unit quaternions, the new solution is more accessible to other researchers who are typically more familiar with orthonormal rotation matrices as a means of representing rotation.

The new solutions of the absolute orientation problem have application in photogrammetry and industrial robot vision. They may also lead to closed-form solutions of related photogrammetric problems such as relative orientation (of importance in binocular stereo) and exterior orientation (of importance in non-stereo robot vision systems).

Motion Vision

The ability to analyze visual motion is fundamental to both biological and computer vision systems, as it underlies a range of vital functions: the detection of sudden movements that might signal potential dangers, object tracking, segmentation of a dynamic scene into distinct objects, and the recovery of the three-dimensional (3-D) structure and movement of object surfaces. These functions are in turn critical to a variety of tasks, such as object manipulation and recognition, and navigation through the environment. Motion analysis has continued to be a major focus of vision work in the laboratory over the past year.

In computer vision, it is customary to approach the motion vision problem in the same way as some approach binocular stereo: by matching points in successive frames. One method that may make the motion vision problem simpler than the stereo problem is the direct use of first derivatives of brightness. Dr. Negahdaripour and Professor Horn previously developed a way of recovering the observer motion from brightness gradients when the scene consists of a planar surface. Dr. Negahdaripour and Dr. Alan Yuille have extended this result to surfaces that can be locally approximated by power series.

In related work, Professor Horn and Professor Edward J. Weldon of the University of Hawaii have found closed form solutions for some special cases when the surface is not restricted to be planar or quadratic. If, for example, there is only rotation, then the motion can be recovered easily and very accurately from a $3\times 3$ matrix whose elements are moments calculated by integrating products of first order brightness derivatives.

The problem is more complex in the case of pure translation. Here the fact that the surface must be in front of the camera to be imaged may be exploited. Recent detailed testing of three competing methods for recovering the direction of the translational motion has shown that the method that minimizes the integral of the estimated depth squared is the most robust. In this method, the direction of translation is the eigenvector corresponding to the smallest eigenvalue of a $3\times 3$ matrix. The elements of this matrix are simple integrals of products of first derivatives of image brightness. If the data is of sufficiently high quality, the smallest eigenvalue will be near zero. In this case one can obtain close approximations without even computing the eigenvalues.

The problem of recovering observer motion in the general case has not been solved yet. Further, the beneficial effects of fixation need to be explored.

Professor Hildreth, Mr. Drumheller and Dr. Norberto Grzywacz are developing a flexible and robust motion measurement system that integrates the fast computation of image velocities with a longer range tracking of localizable image features. A short-range velocity-based system can serve to detect sudden movements, locate object boundaries defined by motion discontinuities, and provide for the rough estimate of the 3-D layout of the scene. A long-range tracking system can provide a more accurate measurement of the motion of image features over a longer time period, for the purpose of recovering a detailed, accurate representation of the 3-D shape of moving objects. Two recent theoretical studies support this approach. First, Dr. Verri and Professor Poggio showed that motion measurements derived directly from the changing image intensities can only be used to derive qualitative properties of the motion field, such as the locations of motion discontinuities. Second, Professor Hildreth and Dr. Grzywacz showed that the accurate recovery of 3-D structure from motion cannot be based on the use of short-range velocity information alone, but requires the integration of image motion information over more extended time periods, effectively requiring a long-range tracking process.

Professor Hildreth and Dr. Grzywacz are also studying the problem of recovering the detailed 3-D shape of moving objects from relative motion in the image. They have extended an algorithm proposed by Professor Ullman, which builds up an accurate 3-D model of a moving object by integrating motion measurements over an extended time, and allows the interpretation of both rigid and nonrigid motions. Professor Hildreth is building a system that uses this algorithm to
recover 3-D structure from natural dynamic imagery. Gene Zilberstein designed a parallel network model that uses a multi-grid strategy to implement this algorithm more efficiently.

Grey-level Matching in Binocular Stereo

Most of the early attempts at building automated stereo systems used simple correlation methods. Recently the trend has been to match features in the two images instead. Typically, edges are used for this purpose. One drawback of these methods is that they provide no disparity information in the image areas lying between edges. The disparity map is sparse and depth has to be guessed at in most places using some interpolation process. Ingenious methods have been developed to provide good interpolation, but one is still only guessing at the true shape between the firm information provided at the edges.

Now consider, for example, a smooth spherical surface illuminated by an extended source, off to the side. The silhouette in both images provides a good edge where matching can occur (although the edges in the two images do not correspond to the same place on the spherical surface). Unless there is sufficient surface texture no other edges will be found. Interpolation from the edge information leads to the conclusion that one is viewing a flat disc, since the distance to the points on the occluding boundary is essentially constant, and the interpolation scheme has no way of telling whether the surface is curved inside the boundary, or whether it is curved inwards or outwards.

Note, however, that the slowly varying grey-level (shading) on the spherical surface can be used to match points in the two images. Mr. Gennert has developed a system based on such an idea proposed by Professor Horn. This new scheme allows grey-level mismatches in a systematic way using a multiplier field. This refinement is crucial to the success of the scheme, since a patch of the surface will rarely be imaged with exactly the same grey-level in the two images of a stereo pair.

The new algorithm has been implemented on the Connection Machine in order to bring its speed up to a level where extensive experimentation is feasible.

NATURAL LANGUAGE

Professor Berwick and his associates are adding a computational dimension to linguistic theory. Their work is based on the assumption that both computational and linguistic viewpoints are necessary for an adequate understanding of natural language processing. Linguistic theory uncovers the representations or data structures required for an adequate understanding of natural language processing, while computer science techniques tell us about the additional computational constraints that make languages easy to learn and understand. Professor Berwick and his students have continued to focus their research on the computational side of government and binding theory, a theory that is both modular and principle-based, reducing much of the variation between languages to differences in a small set of parameters. The past year has seen the first fruits of this line of research.

Professor Berwick completed a systematic analysis of a new approach to parsing using constraints rather than rules, dubbed Principle-Based Parsing, which is to be published by MIT Press. In addition, Professor Berwick was awarded a John Simon Guggenheim Fellowship in order to study this topic in depth during the next year.

Dr. G. Edward Barton completed his thesis work on the computational properties of natural languages. His research has outlined the foundations for a modular, constraint-based view of natural language processing. In particular, Dr. Barton implemented a constraint-propagation method for two-level lexical processing. The constraint-propagation method does not do extensive combinatorial search and, appropriately, cannot solve some unnaturally difficult problems that the two-level model fails to exclude. Dr. Barton has also developed a theory of surface cues for language processing, drawing computer science research on programming language parsing.

Eric S. Ristad has concluded his computational analysis and revision of Generalized Phrase-Structure Grammar (GPSG). Using complexity-theory motivated analysis, he has produced a more constrained version of GPSG that has better linguistic coverage and is more efficient. In addition, Mr. Ristad has analyzed various computational approaches to certain subtle linguistic phenomena, such as conjunctions and sentences of the form, Tell me what adults like and children hate.
Professor Berwick, Dr. Barton, and Mr. Ristad have collected their joint work on the complexity analysis of natural language into a book published by The MIT Press in the spring of 1987. This work has already become well known as inaugurating a new field of study in computational linguistics.

Bonnie J. Dorr is working with Professor Berwick on a principle-based computational model of natural language translation. She has completed a prototype Spanish-English translation system. The design uses a novel co-routine approach that alternates control between structure building and linguistic constraints. Currently she is exploring different ways to compile the constraint information most efficiently. Ms. Dorr is also investigating the differences between Spanish and English verbs, with an eye towards a more polished translation.

Sandiway Fong has studied different ways of encoding government and binding theory constraints in logic, using the PROLOG programming language. He has completed an analysis of several current systems that use PROLOG as a foundation for their representation of linguistic constraints, and is proceeding to build an axiomatic basis for government and binding theory.

The dictionary (or lexicon) plays a key role in current linguistic theory. Two natural language processing projects draw on recent developments in the theory of the lexicon.

Michael B. Kashket completed a new version of his parsing system for Warlpiri, an Australian aboriginal language that exhibits free word order. His parser uses linguistic constraints to interpret the highly permutable sentences, in contrast to other methods that would spell out the many possible sequences in separate rules. The Warlpiri parser is now undergoing more extensive tests on a larger set of sentences collected by the Department of Linguistics and Philosophy. More importantly, Mr. Kashket has begun to show how the same parsing design could be made to work for English, simply by changing the lexicon. If this design is correct, then it will provide the foundation of a single parser design for English, German, French, Japanese, and many, perhaps all, human languages.

Michael R. Brent has built a prototype generation system that will map from a stylized representation of word meanings to a set of sentences that directly express the meaning. For example, the system can take a primitive representation of  cut and can produce sentences such as John cut at the bread or The bread cuts easily. In contrast, with  break it will produce John broke the bread but not John broke at the bread. The mapping process is driven by syntactic parameters and lexical-conceptual structures that are universal across all languages.

LEARNING

Professor Winston’s theory of reasoning by analogy consists of the following parts: an English-understanding module, developed and implemented by Boris Katz, that converts prepared text into relations in a semantic network; a cause-dominated matcher that finds the best possible correspondences according to the causal framework determined by the situations themselves; an analogizing module that reaches conclusions about a given situation by using a remembered precedent; and a rule builder that constructs if/then rules. Professor Winston extended the theory to the problem of learning what things look like from functional definitions, prior knowledge, and particular examples.

Dr. Kirsh has been developing a new approach to planning. Whereas existing AI theories of planning have focused on subgoal ordering, Dr. Kirsh’s approach focuses on resource management. Resources are the limiting factor in action. The heart of the theory turns on viewing an action as something that may use up a resource, produce a resource, ruin a resource, protect a resource, and so on. Precedents are called on to help decide what resources an agent should take on a mission and also to help decide how to control the use of resources. The majority of action-ordering decisions, however, are taken in the field using a small number of resource-related heuristics. This approach has several advantages over planners that treat an action as a mapping from pre to post conditions. Most importantly it provides a way of thinking about planning that explains why constraints should hold between actions or subgoals.

Richard J. Doyle is developing a theory formation system which operates in the domain of physical devices. Given a timeline description of the observable behavior of a device and a vocabulary of primitive mechanisms for the physical system domain, Mr. Doyle’s system, JACK, proposes compositions of mechanisms within the device which can causally explain the observed behavior.
The number of possible hypotheses for even simple devices is unmanageably large. For example, there are on the order of 150 million explanations for the behavior of a toaster, a relatively simple household gadget. Mr. Doyle's approach to making the problem tractable is to identify how behavior is constrained along several dimensions (e.g., time lag, energy gain/loss) when mechanisms are composed. The approach, relatively simple in concept, appears to be considerably powerful. The JACK system generates only about 40 hypotheses for the toaster, without excluding the correct one.

Robert J. Hall is currently investigating the problem of automating the design and optimization of complex information-processing devices, particularly computer programs and digital circuits. The key idea in this work is explanation-based design: every step in the implementation/optimization loop should have an explicit justification in terms of known facts and rules. That is, the program should be able to explain why it takes each step. This raises both epistemological and algorithmic problems. In particular, how should the system represent, index and acquire the knowledge it needs for: (1) a particular application domain, (e.g. banking transactions); (2) understanding the programming or circuit domain where knowledge of data structures are necessary; (3) successful implementation where knowledge of the functionality and performance of computers and computer languages is needed? Similarly, how are explanations to be generated, stored, accessed, and used in guiding the implementation/optimization search? This research is currently in the proposal stage.

Richard H. Lathrop is studying the role of abstraction in learning and reasoning. He implemented a preliminary program that converts a highly detailed room-and-thermostat model into more and more abstract, less and less detailed descriptions, ending with a simple switch triggered by room temperature that turns the furnace on and off. An implementation of the underlying ideas applied to VLSI micro-circuitry demonstrated the automatic inference of low-level hierarchy and explored the use of design precedents to capture and re-use design expertise. Applied to molecular biology protein super-secondary structure recognition, a similar program hypothesized a mononucleotide binding fold structural location for the class of proteins, aminoacyl t-RNA synthetases. Mr. Lathrop also retains an interest in robot arm dynamics. He recently developed the method of local constraint propagation, which for closed-loop robot mechanisms with large numbers of joints (such as the OSU hexapod) is the fastest dynamic simulation algorithm known today.

Kenneth W. Haase is working on programs that discover and use concepts in a variety of technical domains. These programs, called inquisitive systems, learn by synthesizing new representations. Given an initial vocabulary for some domain, they use the empirical properties of the vocabulary to construct new terms and definitions for describing and reasoning in the domain. These new terms—in addition to their practical utility in dealing with the domain—can serve as a new base of vocabulary for further cycles of discovery and extension.

REASONING AND PROBLEM SOLVING

Philip Agre and David Chapman study the dynamics of everyday activity. They have found that realistic domains are characteristically complex, uncertain, and constantly, uncontrollably changing. This makes planning and reasoning with representations very difficult. They have found, however, that concrete activity exploits regular patterns that are independent of representations such as plans or procedures, but rather are products of interactions between a creature and its environment. This insight has led to a new theory of representation which emphasizes indexicality, functional specificity, and grounding in sensorimotor primitives. In particular, they have borrowed from Professor Ullman and Mr. Mahoney's work on visual routines. Mr. Agre and Mr. Chapman are now implementing their theory in a program called Pengi, which is effective in a domain that is too complex, uncertain, and fast-moving for previous techniques to handle. The theories the program is based on are also applicable to the design of robot control systems.

Dr. David McAllester has constructed a knowledge representation system for conceptual mathematics. The system, known as Ontic, has been used to machine-verify the Stone representation theorem for Boolean lattices starting with the axioms of Zermelo-Fraenkel set theory. The Stone representation theorem is a fairly sophisticated theorem, similar in complexity to the Tychonoff theorem in topology which states that an arbitrary product of compact spaces is compact. The results of this verification indicate that, given an appropriate library of background facts, Ontic's theorem proving mechanisms are powerful enough to verify machine-readable "proofs" which are only one to three times longer than the natural language proofs found in textbooks.

Ontic's workings are based on new constraint propagation inference mechanisms which manipulate labelings of a semantic-net like graph structure. These new mechanisms implement a form of inheritance based on congruence closure and a
propagation rule for automatic universal generalization. The inference mechanisms, in particular the inheritance mechanism, only deduces statements about a given set of focus objects; by specifying focus objects the user focuses the forward chaining constraint propagation inference process. Dr. McAllester will continue his research in mathematical knowledge representation by exploring applications to software verification, interactive knowledge bases, and common sense reasoning.

Jonathan Rees and Ramin Zabih have continued to develop new formalisms for mechanically encoding mathematical knowledge using Ontic. Machine-verifiable proofs expressed in the Ontic language are typically less than a factor of two longer than ordinary textbook presentations. This is a significant improvement over previous verification systems. Using the Ontic language, Mr. Rees has encoded a substantial corpus of formal mathematics, starting with set theory and going through point-set topology to develop properties of the real numbers.

Dr. McAllester and Mr. Zabih have developed an interpreter for a language that combines lambda calculus with McCarthy's AMB operator—a primitive that expresses nondeterministic choice. Their paper on this system won a publisher's award at AAAI-77.

On another front, Dr. Fanya S. Montalvo is working on the problem of diagram understanding; a way of communicating with a computer graphically, in a manner analogous to the way natural language understanding permits verbal communication. This area centers on the overlap between computer vision and computer graphics; that is, dealing with questions about the representation of visual knowledge. The work involves building a visual vocabulary and a way of attaching diagrams to specific pieces of an application and testing the vocabulary using humans in the graphic interaction loop. The technique of involving humans in a closely coupled interaction loop is seen as a means of extracting visual knowledge from people, knowledge that would otherwise be non-introspectable. It is a way of making visual heuristics and symbolic descriptions more explicit.

MODEL-BASED REASONING SYSTEMS

Professor Davis, Dr. Shrobe, and their associates are building knowledge-based systems that use knowledge about structure, function, and causality to perform a wide range of problem solving and reasoning tasks. Previously, expert systems have typically been built from large collections of empirical associations. This work relies instead on a detailed model of the structure and function of a device, allowing it to reason about how the device works and how it fails, in a manner similar to an experienced engineer.

Building and using such a model represents an important advance in the art of expert systems construction, because it provides the system with a more fundamental understanding of the device than is possible using the traditional approach. While the current work focuses on digital circuits because of their tractability and significance, the larger concern is reasoning about devices in general, understanding how they work and how they fail.

The work has explored multiple uses of descriptions of structure and behavior. These descriptions are used for a range of tasks, including candidate generation (determining which components of a circuit can account for observed malfunction), designing tests to distinguish between candidates, and test programming (designing a comprehensive collection of tests that verify correct device operation).

This approach is capable of handling a wide range of faults, including such things as bridges and errors of incorrect assembly, faults that are not handled by traditional approaches to troubleshooting.

Walter C. Hamscher extended these techniques to apply to more complex designs that include memory and behavior over time. He showed that the problem of diagnosing circuits with memory is fundamentally underconstrained, and he explored the utility of several different behavioral abstractions as ways of constraining the problem. He is currently developing an advanced set of such abstractions, using as a motivating example a board-level circuit from a high-performance workstation computer. This requires finding ways to reason about and represent complex time-varying behavior.

Harold J. Haig designed and implemented a hardware description language based around the vocabulary typically used by hardware architects and designers, making the resulting language compact and readable.
Mark H. Shirley is building a system capable of generating diagnostics from a circuit description. Unlike traditional programs that work with gate-level descriptions, this system uses knowledge about how to test high-level components (such as ALU's or memories) and knowledge about standard usage patterns of devices (such as how an I/O interface is typically used) to develop high-level plans for device testing. The result will be a system that is capable of generating tests for devices considerably more complicated than those handled by existing test generators. A paper describing this work was designated “Best Paper” in the Engineering Track of the 1986 Conference of the American Association for Artificial Intelligence.

Peng Wu is developing a system that functions as an assistant in design for testability (DFT). Most work on DFT approaches the problem by requiring the designer to use techniques like level-sensitive scan design throughout the circuit that guarantee testability; some work has suggested exhaustive addition of built-in testing hardware. In either case indiscriminate application of these techniques comes at a high price in added hardware. A central theme of Mr. Wu’s work is that techniques to ensure testability should be used only in those places that are known to be inaccessible to a competent test design system. His program thus takes as input the circuit design, the results of Mr. Shirley’s program, and pays particular attention to the places where that program failed and the reasons why it failed. Those specific failures become the testability goals that are the focus of Mr. Wu’s program, which then will choose DFT techniques appropriate to the specific situation.

Brian C. Williams is working on a novel approach to circuit design. Where traditional systems have been based on a library of standard designs, this system focuses on design based on fundamental principles of qualitative physics and qualitative mathematics. A design is constructed using a generate-and-debug paradigm, combining both qualitative and quantitative information. The design space is explored by first constructing a circuit that produces the desired behavior at the qualitative level, then shifting to the quantitative level to satisfy the design’s performance requirements. It will thus provide the ability to generate novel circuit topologies where needed, in addition to using the traditional library-based approach.

Paul Resnick is exploring how programs can learn from experience. Good human troubleshooters can reason from a knowledge of structure and behavior to “figure out” why something doesn’t work, but they also remember that experience, can generalize it, learn from it, and, recognizing variations of it later, can save considerable time and effort. One key problem in doing this is knowing how to generalize, what to change to turn a specific experience into a more general pattern. Mr. Resnick is exploring how knowledge of structure and behavior can be used to guide such generalization. Given a fault in a specific component of a device, for example, we may wish to explore what symptoms would arise if the same fault were to occur in other, “similar” components in the device. In this case “similar” might mean components playing the same role, demonstrating how we can exploit knowledge of the device’s structure and behavior.

Three other projects form a second component of Professor Davis’ expert-systems work. First, Reid G. Simmons is working on a system to do geologic interpretation. This effort focuses on developing a program that understands and is capable of reasoning qualitatively about geologic processes responsible for formations and deposits. This capability is combined with a traditional rule-based expert system to provide a more robust system than is achievable with the expert system alone. The combined system uses the rule-based system most of the time for efficiency reasons, but can fall back on the “first principles” geologic reasoning system for help in novel situations.

Second, Mr. Jeffrey Van Baalen is working on the challenging problem of selecting representations; attempting to understand what we mean when we call something a good representation. The work currently proceeds by studying in detail the kinds of representations used in several verbal reasoning problems. Of particular interest is the evolution of representations employed in the course of trying to solve a problem, because every representation discarded has a specific shortcoming which each new variant is designed to correct. The ultimate goal of this work is a set of design principles that would permit the analysis of a problem, followed by the selection (and perhaps creation) of a representation well suited to it.

Third, Daniel Weld has been investigating problems involved in reasoning about the behavior of physical systems. He has developed a program capable of unifying discrete and continuous process models of change. Traditionally, two notions of process have been used in programs that reason about change: discrete models, which represent changes as instantaneous; and continuous models, which represent changes as processes that act gradually over time. Mr. Weld’s system, called PEPTIDE, uses a technique called aggregation to unify the two types of models, permitting both to be
used when performing qualitative simulation, thereby allowing a simulator to switch back and forth between different types of models depending on expediency.

More recently Mr. Weld and Professor Lozano-Pérez have been working on the problem of comparative analysis: predicting how and why a system will react to perturbations in its parameters. We might, for example, want to determine what will happen to the period of an oscillating spring/block system if the mass of the block were increased. He has developed a system capable of determining the answer and supplying an explanation of the result, using a newly developed technique called differential qualitative (DQ) analysis.

**PROGRAMMER'S APPRENTICE**

Dr. Rich, Dr. Waters, and other members of the Programmer's Apprentice group use programming as a domain for studying and attempting to duplicate human problem solving skills. Recognizing that it will be a long time before it is possible to fully duplicate human abilities in this domain, the near-term goal of the project is the development of a system, called the Programmer's Apprentice, which provides intelligent assistance in various phases of the programming task. From an artificial intelligence perspective, the two main issues in the project are the representation of programming knowledge and reasoning with this knowledge. A formal representation for programs and programming knowledge, called the Plan Calculus, was developed early in the project.

Dr. Rich and Dr. Yishai Feldman have completed a first release of CAKE, a layered knowledge representation and reasoning system, which will support the next phase of research on the Programmer's Apprentice. The facilities provided by CAKE include: truth maintenance, unit propositional resolution, pattern-directed invocation, equality, a type lattice, algebraic properties of operators (transitivity, associativity, commutativity, etc.), reasoning about finite sets, frames, and an implementation of the Plan Calculus.

Dr. Waters has developed a new programming language feature, called Synchronizable Series Expressions, which allows most loops to be written in a much more concise, functional notation. He has implemented this feature in Common Lisp as a macro package which automatically transforms these expressions into efficient loops before evaluating them. Using this package, programmers incur no runtime overhead as compared to writing the loops themselves. The package has been in use in the Laboratory for over a year. An Ada implementation of the feature is under design.

Howard Reubenstein is working on a prototype Requirements Apprentice to assist a systems analyst in the creation and modification of software requirements. Unlike current requirements analysis techniques, which assume a formal description language, the main focus of the Requirements Apprentice work is on the earliest phases of creating a requirement in which incompleteness, ambiguity, and contradiction are inevitable features. The central problem the Requirements Apprentice faces is one of knowledge acquisition. It has to develop a coherent internal representation from an initial set of disorganized statements. To do so, the Apprentice will rely on a variety of techniques, including dependency-directed reasoning, hybrid knowledge representation, and the reuse of common forms (clichés).

Jeremy Wertheimer has completed a theoretical study of the programming knowledge underlying inference systems. This work is motivated by the observation that "inside every big program there is a small program." The programming methodology implied by this work is to start with a core "small program" from a library, and to elaborate it into the desired "big program." Mr. Wertheimer has identified the small programs at the core of the inference domain and a number of domain-independent elaborations which cover a large space of variations, including many well-known inference systems, such as OPS, GPS, EL, AMORD, RUP, and Prolog.

Yang Meng Tan has implemented a cliché-based program structure editor, called ACE. ACE extends the syntax-directed paradigm of program editing by adding support for programming clichés (standard algorithmic fragments). ACE supports the rapid construction of programs through the combination of clichés selected from a cliché library. ACE is also innovative in the way it supports the basic structure-editor operations. Instead of using the standard grammar for a programming language, ACE uses a modified grammar which is designed to facilitate editing. Uniformity of the user interface is achieved by encoding the modified grammar as a set of clichés.
MIXED SYMBOLIC AND NUMERICAL COMPUTATION

This project is concerned with the development of new computer representations and reasoning mechanisms that will enable intelligent systems to autonomously design, monitor, and understand complicated physical systems, through appropriate mixtures of numerical and symbolic computing.

Research has proceeded along several fronts, including: demonstrating a prototype system that automatically constructs numerical simulations of dynamical systems and automatically builds these into procedures to perform qualitative analyses; isolating some of the central issues that must be addressed by a machine that can plan, execute, and analyze the results of numerical experiments to arrive at global geometric descriptions of long-term dynamical behavior; designing several computers that are appropriate for high-performance mixed numerical-symbolic computations, and fabricating preliminary versions of each; and contributing to the standardization of a kernel dialect of Lisp that is appropriate for direct realization in hardware and for multiprocessing applications.

Automatic Preparation of Numerical Experiments

Professors Sussman and Abelson have implemented a prototype dynamicist's workbench: a software environment for exploring dynamical systems. It provides a spectrum of computational tools—numerical methods, symbolic algebra, and semantic constraints. These tools are designed so that combined methods, tailored to particular problems, can be constructed on the fly. One can use symbolic algebra to automatically generate numerical procedures; one can use domain-specific constraints to guide algebraic derivations and to avoid complexity; and one can use numerical methods to identify and verify qualitative properties of systems.

These ideas have been demonstrated in the context of several dynamical systems initially formulated as electrical networks. Given such a network description, the workbench generates the algebraic constraints and other information needed to support analysis. The workbench evolves the state of a dynamical system by automatically compiling a procedure to compute the system derivative, and then combining this with an appropriate numerical integrator composed from primitive integrators and one of a number of strategies for adaptive step-size control. These system-derivative procedures generated by the workbench may incorporate iteration schemes when the state-variable derivatives cannot be expressed in closed form. The workbench also automatically compiles procedures that compute the frequency response of linear systems. This requires substantial symbolic manipulation, which is made tractable by using semantic markers to guide the algebra. One can explore the complex dynamics of systems such as the driven van der Pol oscillator. Here the workbench automatically compiles numerical procedures for finding periodic orbits and for tracking them as the system parameters vary.

Automatic Planning and Analysis of Numerical Experiments

Kenneth Yip is now implementing a prototype interactive system that will help scientists and engineers to plan, execute, and analyze numerical experiments. One should be able to specify a dynamical system and discuss with the computer the effects of small perturbations and different forcing functions. The central issues to be resolved in constructing this system are: the expectation problem; deciding what to try next in planning a numerical experiment and the shape problem; recognizing and describing geometrical objects in phase space. Mr. Yip has proposed an approach to this task based on local analysis of bifurcations, analogous to Waltz's constraint analysis of line drawings.

Architectures for Numerical and Symbolic Computing

Henry Manyan Wu has designed a computer, Scheme-86, that is optimized to execute the Scheme dialect of Lisp. Mr. Wu's design reflects the fact that symbolic manipulation is a memory-intensive process, often involving chasing down several levels of indirect references during operand fetching.

Mr. Wu, together with Dr. Yekta Gursel, began a board layout of the processor in the spring of 1986. Since then Andrew A. Berlin has worked on the implementation of the Scheme-86 processor board. With help from Oded Feingold, and excellent advice from Bob Parker at MOSIS, David A. Espinosa has completed the layout of the Scheme-86 memory boards.
As part of the Scheme-86 board design effort, several analysis tools for printed-circuit board designs were implemented. These include a set of connectivity extraction tools and a design rule checker. We expect that these tools will prove valuable for use in future hardware projects. Jerrold L. Boxerman has built a PAL tester and a memory-chip tester. He is currently designing a high speed testing device which will be used to test the Scheme-86 memory boards. Mark Miller has revised the simulation information for Scheme-86, and has re-simulated the timing of the Scheme-86 processor.

James N. Rees has extended Mr. Wu's pc-board layout system to include bus wiring commands and some advanced graphics functions. This layout system has proven useful to several other research groups. For example, at MIT this system is now being used by the Parallel VLSI architecture group to design a routing board and at Berkeley's Spur project, Benjamin Zorn is analyzing the layout system to determine data flow patterns in large Lisp systems.

Dr. Gursel has designed and built a prototype extremely high-performance floating-point processor that interconnects multiple execution units by means of a very fast crossbar. This allows the programmer to dynamically reconfigure the architecture to allocate arithmetic units during a computation. Dr. Gursel's design looks like a way to achieve supercomputer performance with a modest hardware cost.

INTELLIGENT SUPERCOMPUTING

Message-Passing Semantics

The Message-Passing Semantics Group, under the direction of Professor Hewitt, is developing the foundations for large-scale parallel systems that perform robustly in changing environments. Such systems are composed of autonomous computational agents, called Actors, which communicate by passing messages. The Message-Passing Semantics Group is developing the foundation for systems with subsystems that have conflicting goals and an incomplete, inconsistent representation of the world. Such systems are open because they continually change: some change coming from within, through message-passing between internal agents, some from without through interaction with the outside world. Professor Hewitt's actor model provides a suitable basis for developing this concept of an open system because it supports dynamic reconfigurability, compositionalty, and extensibility. The group's research focuses on theoretical, architectural, and linguistic aspects of actor systems.

Professor Hewitt and Dr. Gul Agha developed an abstract model for Actors to support open systems. Dr. Agha has also provided a semantics for Actor languages that leads to a better understanding of concurrent systems in their full generality.

Carl R. Manning is working on the implementation of computer languages based on the Actor model of computation and the design of multiprocessor architectures to run these languages. Over the last year he designed a new core Actor language which implements many core constructs needed for developing higher level concurrent languages. He also implemented a compiler for this language which produces code in a primitive Actor language based on Dr. Agha's theoretical work, so that programs may be run on the machine emulator for actor programs. He is evaluating extensions to this language and investigating the issues associated with implementing it on a variety of multiprocessors.

Thomas J. Reinhardt is presently implementing an actor-based library of Common Lisp routines. In addition, he is investigating high level resource management protocols and advanced control structures to support the Message-Passing Semantics Group's ongoing research into large-scale concurrent applications.

S. Peter de Jong pursued research in the creation of an artificial intelligence system to model and control large organizations. A large organization is characterized by parallel activities which occur within multiple, independently developed, local models. His approach is to create a system called Ubik which contains a language for representing organizational knowledge, action, and reasoning. The Ubik language is based on a tight unification of the following: the actor model of parallel computation, a theory of concepts, contexts, and prototypes; and a control and focusing mechanism called sponsors. The language is used for organizational activities such as the description, communications and coordination of applications running within the distributed models, problem solving within the organization, and maintainence of constraints between the concepts which describe the organizational structure and activities. Part of Ubik's research goals is the automatic reorganization of organizational concepts to match changing environmental conditions.
Concurrent VLSI Architecture

The Concurrent VLSI Architecture Group under the direction of Professor Dally is developing techniques for applying VLSI technology to the construction of high performance concurrent computer systems. The group is currently working on the design of the J-Machine, a fine-grain message-passing concurrent computer. In addition to offering performance of $10^8$ times a conventional mainframe, the J-Machine will test a number of new concepts in interconnection networks, addressing mechanisms, processor architecture, computer arithmetic, and concurrent software systems.

Professor Dally has developed a queuing model that accurately predicts the performance of $k$-ary $n$-cube interconnection networks (e.g., hypercubes, tori, meshes, and rings). The model predicts network latency and throughput as a function of offered traffic. These predictions agree within 10 percent with experimental results. The model has been used to show that the highest performance network for a given cost is a low-dimensional network ($2 \leq n \leq 4$ and $8 \leq k \leq 64$) not a binary $n$-cube or hypercube as was previously thought.

Professor Dally and Paul Song have designed a communication chip, the Network Design Frame, that puts this theory into practice. This chip uses a new partitioned data path architecture, a token-passing arbiter, and virtual channels to perform wormhole routing in 2-D meshes. It will be used to implement the communications network for the J-Machine. Simulations indicate that this chip will route a 6-word (216-bit) message across the longest path of a 4096-node network in $5\mu$s. A test chip containing key components of the Network Design Frame has been submitted for fabrication.

The entire group has been working on the design of the Message-Driven Processor (MDP), the symbolic processing element for the J-Machine. The MDP reduces the overhead and latency of dispatching a task on message arrival to $\approx 1\mu$s making possible the execution of programs with very fine-grain (10 instructions/grain) concurrency. This performance is achieved by directly executing and buffering messages under hardware control. To support dynamically-typed languages such as LISP, the MDP is a tagged machine. The tags are also used to implement futures and access to remote data. The MDP uses a novel memory organization that permits both indexed and associative access and that incorporates instruction and queue buffers to effectively triple the memory bandwidth. Waldemar Horwat has written an assembler and an instruction-level simulator of the MDP that are being used to evaluate the architecture and to develop systems software. Andrew Chien and Linda Chao have written a register-transfer level simulation of the machine that is being used to collect timing information and to guide the low-level hardware design.

To provide numerical computing power for the J-Machine, Professor Dally and Stuart Fiske are developing a Reconfigurable Arithmetic Processor (RAP). The RAP is a 100MFLOPS floating-point arithmetic chip that is being designed to test the concept of exploiting locality by mapping equations directly into a configuration of many digit-serial arithmetic units. By recycling intermediate results, this approach reduces the required I/O bandwidth by more than an order of magnitude. With VLSI technology, it is this I/O bandwidth that limits the performance of arithmetic units. A test chip containing several fixed-point digit-serial arithmetic units connected by a statically configurable switch has been submitted for fabrication.

Professor Dally has written a compiler for Concurrent Smalltalk, a programming language based on Smalltalk-80 with extensions for concurrency. The language is being used to experiment with abstractions for concurrency such as concurrent data structures. The compiler currently generates an intermediate code (quadruples). Work is underway to write an optimizer and a code generator for the MDP.

Professor Dally and Brian Totty are in the process of writing a J-Machine operating system (JOSS). JOSS will test several new concepts involving method caching, concurrent virtual memory, name recycling, concurrent garbage collection, and message services. The primitive memory management components of the kernel have been coded and are being debugged on Mr. Horwat’s MDP instruction simulator.

BASIC THEORY

Professor Minsky’s research continues developing a theory of human thinking and learning called the “Society of Mind” theory. In March 1987, Professor Minsky’s group published a major book, The Society of Mind, on this subject. One aspect explores how to combine knowledge representations that apply to different realms of thought; how to construct effective schemes for making and applying analogies. Another aspect is a “re-duplication” theory of language, in which grammatical
forms are seen treated as emerging from expressive requirements, rather than from conventions that communications are forced to fit. We have also made progress in unifying two concepts that previously had seemed quite separate: the ideas of Frames and of K-lines. The unified formulation suggests new ways machines could learn to construct and use new kinds of descriptions.

Most of the knowledge in a Society of Mind system is represented not as symbolic expressions, but in the network of connections between various processes. This connects our work with that of the newly popular "connectionist" theories of learning in parallel distributed computing systems.

PATRICK H. WINSTON
The Biotechnology Process Engineering Center (BPEC) has continued to grow and develop since its establishment at MIT on May 1, 1985. Renovation of a 1,477 ft² tissue culture laboratory in Building 20A was completed in December of 1986 and renovation of two laboratories for microbiology, totalling 2,408 ft², has been initiated.

Thirty-six research projects, involving 18 faculty members from the Departments of Chemical Engineering, Biology, Applied Biological Sciences, Electrical Engineering and Computer Science, and Nuclear Engineering, and the Whitehead Institute for Biomedical Research, are being pursued under four research thrust areas:

- Genetics and Molecular Biology
- Bioreactor Design and Operation
- Downstream Processing
- Biochemical Process Systems’ Engineering

Two new interdisciplinary projects were introduced this past year: "Controlled Protein Secretion in Mammalian Cells" (Departments of Chemical Engineering and Applied Biological Sciences and the Whitehead Institute for Biomedical Research) and "Antibody-Assisted Protein Refolding" (Department of Chemical Engineering and the Whitehead Institute for Biomedical Research).

New courses taught by BPEC faculty members enjoyed great success. Two courses intended for undergraduates, 7.52J/10.56J/20.803J Biotechnology of Mammalian Cells and 10.507 Biotechnology for Fun and Profit, were well attended by both undergraduate and graduate students. Another new course, 10.57J Modelling of Biological Systems, had a graduate enrollment of 20 students. The previously established 10.59J/20.811J Biochemical Engineering will be further improved by the in-class viewing of videotapes on the subject of industrial practice in biochemical engineering. Funded by a grant from National Science Foundation (NSF), footage for three videotapes on different aspects of commercial fermentation operations was shot on location at two different industrial sites by BPEC staff and a professional video production team. The tapes will be ready for use in the classroom for the 1987-88 academic year.

Through the Undergraduate Research Opportunities Program (UROP), the BPEC extended research opportunities in biotechnology to the entire undergraduate community. Between the Fall of 1986 and the Summer of 1987, 105 UROP positions (97 for pay and eight for academic credit) were supported. In addition, during the Summer of 1987 the BPEC will implement the NSF’s Research Experiences for Undergraduates (REU) Program and hire ten students from other schools and universities to participate in research. Presently, 53 graduate research assistants, 16 post-doctoral research associates, and 28 research and support staff from the five departments and the Whitehead Institute for Biomedical Research are associated with the activities of this Center.

The second BPEC Symposium was held at MIT in October of 1986. More than 350 representatives from the chemical, pharmaceutical, biomedical, and biotechnology industries, as well as over 100 people from academia and government, attended the Symposium. The proceedings of this Symposium were videotaped by the Center for Advanced Engineering Studies and the tapes have been made available through the Industrial Liaison Office for rental or purchase.

Acting as both an educational opportunity and a forum in which representatives from industry could exchange ideas with both academicians and other persons from industry, three biotechnology-related short courses, including a new short course in Downstream Processing, were presented at MIT during the Summer of 1986. These courses were attended by over 300 representatives from industry and eight BPEC faculty members participated as directors and/or lecturers.

The Biotechnology Process Engineering Center Consortium (BPECC), a collection of member companies established to provide a direct and cooperative interface between the BPEC and industry, continued to grow as it added another 16 members this year bringing its total membership to 43 companies. BPEC faculty, students, and staff have had numerous interactions with Consortium members including special symposia, joint research projects, sabbatical exchange programs for both Consortium member representatives and BPEC students, and personnel recruitment for industry.

Two BPEC Mini-Symposia/Workshops for Consortium members were held this past year. The first Workshop, entitled "Downstream Processing", was held July 14-15, 1986 at MIT. Twelve BPEC members and 47 Consortium member representatives attended. The second Mini-Symposia/Workshop was held on May 15-16, 1987. This Workshop, entitled "Bioprocess Control and Scale-Up", was given by six BPEC faculty, was attended...
by 37 Consortium member representatives, and featured practical examinations of various aspects of bio-
process control and scale-up. At each of these Workshops, all presentations were followed by an "open"
discussion which facilitated interaction among the attendees and the BPEC faculty.

The BPEC has been recognized as an enviable prototype for centers of biochemical engineering. Several
distinguished visitors, including the Minister of Science and Technology of Australia, a Director of
National Efforts in Biotechnology for Argentina, and the Governor of Minnesota, as well as numerous
representatives from American universities, have visited the BPEC this past year to observe how the
Center works so that they might recreate the success of the BPEC with their own centers. As a testament
to the quality of the research conducted at the BPEC, the BPEC now has associated with it eight visiting
scientists from industrial and academic organizations around the world.

DANIEL I.C. WANG
The Center for Advanced Engineering Study (CAES) was founded in 1963 for the purpose of developing educational programs that provide opportunities for practicing engineers, scientists, and managers in industry, government, and educational institutions to attain and maintain the competence needed to exert technological leadership. Alfred P. Sloan Jr. provided both the impetus and the funds to get the Center started. Building 9 has been the home of CAES since its completion in 1968. This year brought new leadership to CAES. The new Director is Dr. Shaoul Ezekiel, Professor of Aeronautics and Astronautics, and Electrical Engineering and Computer Science.

To achieve its objectives, CAES offers two types of educational programs, on-campus and at the workplace, for the practicing professional. The on-campus program, called the Advanced Study Program, directed by Dr. Paul Brown, provides the participants with individualized study and/or research that is tailored to their backgrounds and designed to meet their needs and the objectives of their employers. For learners at the workplace, the Center provides studio-based and classroom-based video courses, as well as videotaped symposia which are produced at the Center in collaboration with MIT faculty and research staff. Richard Noyes is the director of the video-based programs.

During the 1986-87 academic year, 68 professionals participated in the Advanced Study Program, 30 from the United States and 38 from 15 other countries. These Fellows attended regular graduate and also undergraduate subjects that suited their needs. In addition, many of them performed individualized studies guided by faculty members and several participated in on-going research programs. Moreover, the Center sponsored several subjects that are of particular interest to the Fellows, such as Project Management, Systematic Policy Analysis, and Managing Technological Change. These subjects are listed in the catalog and are, of course, open to MIT students. CAES also offered informal day/evening classes in Modern Computer Concepts, Mathematics, and English as a Second Language.

The Fellows in the Advanced Study Program are provided with study offices, computer facilities, and a videotape library with viewing facilities. During the past year, the computer facilities were expanded to handle projects in artificial intelligence and expert systems. Also during the past year, we organized a weekly luncheon seminar at which the Fellows gave brief presentations on their work. Center staff and faculty also made presentations at these seminars.

In video-based education, the Center has produced and marketed several new video-courses/publications during the past year. These include: Electronic Feedback Systems by Professor James Roberge; Finite Element Procedures for Solids and Structures-Nonlinear Analysis by Professor Jurgen Bathe; Signals and Systems by Professor Alan Oppenheim; Structure and Interpretation of Computer Programs by Professors Harold Abelson and Gerald Sussman; Out of the Crisis by Dr. W. Edwards Deming; and Microprocessors: Hardware, Software, and Applications by Christopher Strangio. This brings the total number of CAES video-courses to 53.

Several new video-courses are currently in development. These include: Advanced Composites by Professors James Mar and Paul Lagace; Materials Processing Operations: Mathematical Modeling by Professor Julian Szekely; Machinery Noise and Diagnostics by Professor Richard Iyon; System Dynamics by Professors Jay Forrester and John Sterman, and David Kreutzer; Data Networks by Professors Robert Gallager, Dimitri Bertsekas, and Pierre Humblet; Design of Complex Electronic Systems for Production by Curt Brown and others from Industry and MIT; Industrial Chemistry by Professor Raymond Baddour; Analysis of Welded Structures by Professor Koichi Masubushi; Management of Innovation by Professor Eric von Hippel; and Image Processing by Professor William Schreiber.

During 1986-87, CAES began a new venture in video-based education by videotaping a number of MIT symposia on current research activities for timely distribution to industrial organizations and educational establishments. The symposia, which were organized by the Industrial Liaison Program, included such diverse topics as Manufacturing in the 1990's; Expert Systems from the Users Perspective; Science and Technology of Manufacturing; Metal and Ceramic Matrix Composites; and Biotechnology Process Engineering. In addition, the Center videotaped Future Directions in Electronics—the 40th anniversary symposium of the Research Laboratory of Electronics.
Because of the large increase in video recording activities, the Center has initiated the construction of a television studio complex in building 9, which is scheduled for completion in October 1987. The availability of this studio, aside from being cost effective, will significantly increase both faculty and Center staff productivity, and will enable the Center to refine the production of video-based educational programs, as well as facilitate the adaptation of new video technologies. Television recording and production equipment have already been purchased and used to videotape several of the symposia mentioned above. In addition to the studio complex, rooms 9-150 and 9-253 have been prepared for videotaping live classroom presentations and symposia. Since January 1987, CAES video programs have been produced entirely with Center staff and Center-owned equipment.

In addition to the above, the Center has been reorganized with emphasis on, among others, combined video and conference management, inhouse print publishing, integrated financial management, unified client support, broad-based staff training, and computer networking. As an additional part of the reorganization, Richard Noyes was appointed Associate Director as of 1 July 1987.

The Center also participated in a unique initiative to provide continuing education for electrical engineering faculty in US colleges. This program grew out of a workshop on lifelong learning for electrical engineering faculty organized by Professors Louis Smullin and William Siebert of the department of Electrical Engineering and Computer Science and held at MIT in November 1986. Seven two-week long intensive courses were offered during the summer of 1987 by three universities and four industrial organizations. The topics varied from Artificial Intelligence to Digital Signal Processing. One hundred and twenty-five faculty members from 75 colleges in 36 states will have participated in this initial phase of the program. CAES played a key role in the organization and coordination of this program under the aegis of the American Society for Engineering Education (ASEE).

Future Center plans include: strengthening of the Advanced Study Program by offering half-time and quarter-time participation, which would be of particular interest to local industry; videotaping of ILP symposia scheduled for next fall, such as, High Temperature Superconductivity, Modern Speech Processing, Frontiers in Metallurgical Research, and Impacts of Information Technology on Industries, Organizations, and Individuals; broadening the fields and disciplines covered by Center produced video courses; and performing research in educational methodologies and adaptation of new technologies for delivery of educational programs. In addition, the Center is placing special emphasis on the development of collaborative educational programs, specifically, with local industrial organizations.

SHAOUl EZEKIEL
In its first full year of operation, the Center for Technology, Policy and Industrial Development (CTPID) has implemented several of its most important objectives, added new projects, and continued to support research and education in science-and technology-intensive policy issues. Of particular note this year have been the fruition of the research of the International Motor Vehicle Program; the foundation and implementation of the Program on Hazardous Substances Management; and the participation of many Center affiliates in the MIT Commission on Industrial Productivity.

The Center was established in June, 1985 by the Provost and the Dean of Engineering on the recommendation of an Institute Committee chaired by John D.C. Little of the Sloan School of Management. The Little Committee's decision recognized that we live in a complex society in which science and technology are continuously introducing change. The change creates a stream of public policy issues, whose proper resolution requires technological expertise, understanding of the policy-making process, and analytical skill. MIT, which has always been interactive with society and responsive to national and international needs, can and should play a leadership role in public policy research.

The Center brings together a wide range of resources and activities at MIT in science, engineering, the social sciences, and management to create a new synergy to apply to resolving issues with significant scientific and technological components. In addition to the sharing of perspectives from within the Institute, public and private sector inputs have been actively sought. The three major objectives of the Center are to:

* examine how technology affects society and how public policy may be applied to design and direct policy in a responsible manner;
* discover the forces that drive technological development in both public and private sectors; and
* determine the best ways to manage the harmful side effects of technology.

Research at CTPID is aimed at developing and applying new quantitative and qualitative approaches to technology and policy issues. Innovative approaches to quantifying relevant factors will contribute to the overall decision-making process when technical judgments must be made. However, even if all facts were perfectly known, and their risks quantified, our current systems for decision making would often generate divisive adversarial debate and forestall timely resolutions. Therefore, concurrent with the pursuit of technically sound bases for decisions, the Center is promoting the development of more effective decision-making techniques such as risk assessment, risk management, and negotiation.

Science-and technology-intensive policy decisions frequently take place in an atmosphere of strong, often extreme position taking and under pressures of time and expense to the parties involved. Through the Center, MIT with its dual traditions of responsiveness to public issues and academic neutrality, can provide objective analyses of policy options, rather than support for any particular position. In all its major initiatives, CTPID has included the perspectives of leaders in government, industry, and labor. Center projects routinely go beyond basic research to implementation activities to demonstrate how an interface between technology and policy may be effected.

An Advisory Board of leaders from the public and private sector is being formed to strengthen the links between Center initiatives and the implementation of research. The board will hold its first meeting in Fall 1987.

RESEARCH

The Hazardous Substances Management Program

The Hazardous Substances Management Program is a major MIT initiative being administered by the Center. The Institute has made the problem of hazardous substances a concern of highest priority for research and education for the next decade. In the past year the overall program has moved from the planning to
the implementation stage. It is designed to explore the problems posed by hazardous chemicals emanating from all sources, including purposeful use, effluents from manufacturing, and the disposal of wastes.

The basic research to be pursued under the program is designed to lead to fundamental scientific, technological, and policy breakthroughs. Three objectives underlie this effort.

*Those working in this area will develop new approaches to public and private decision making that can break the present logjam surrounding siting, regulation, and policy making. They hope to replace technocratic, top-down approaches to policy and conflict resolution with a consensual, participatory approach to policy development and conflict avoidance.

*Researchers are developing new methods to provide direct evidence of the effects of chemical exposure on human health that will permit wiser setting of priorities, technological approaches, and objectives for risk management. The aim is to replace the present inferential basis for science-intensive decision making, fraught with uncertainty and implicit value judgments, with a more scientifically defensible system.

*MIT and industry scientists will work together to develop innovations in product and process technology that will help us avoid the creation of wastes and dangerous products in the first place. The shift is obvious—from emphasis on waste management to waste reduction and elimination.

These long-term paradigm shifts will be augmented and supported by new knowledge gained through research aimed at problems requiring immediate solutions. The immediate results of the programs will be advances in the technologies available to solve short-term problems, particularly applications of incineration and the resolution of current disputes over the safety of these technologies. In the long run, the program should produce permanent changes in our overall approach to hazardous substances.

The educational component of the program is designed to provide a strong program for both undergraduate and graduate students specializing in this field. Four initial courses are being offered in this area sharing a common theme: Chemicals in the environment. The first two were offered in Spring 1987 and were subtitled "Sources and Control" and "Chemicals and Human Disease". They will be augmented in the 1987-88 academic year by two more courses subtitled "Fate and Transport" and "Policy and Management".

The involvement of industry is critical, not only to supporting the program but also to identifying accurately the general and specific points at which problems may be avoided or most economically resolved. Like the International Motor Vehicle Program, the Program for Hazardous Substances Management will actively seek ideas from the industrial sector. A committee of industry and government representatives will advise the MIT faculty group determining the research agenda. Insights from the three sectors will be shared through technology transfer, joint research projects, seminars, and other mechanisms.

The program underway is being shaped by a group of faculty members, the Hazardous Substances Group, presently including Professors David Marks, Head, Civil Engineering; Adel Sarofim, Chemical Engineering; Lawrence Susskind, Urban Studies and Planning; William Thilly, Director, Center for Environmental Health Sciences; and Professor Roos. Dr. John R. Ehrenfeld, Senior Research Associate at CTPID, is coordinating the program and will also teach two of the four basic courses.

Support for the program comes from both government and private sector contributions. A major part of the funds for seed research, academic activities and fellowships, and outreach is being sought from industry. The Dow Chemical Company has become the first of ten founding corporations to support the program.

The International Motor Vehicle Program

The International Motor Vehicle Program (IMVP) was established to assess the major policy choices facing the auto-producing world. The multimillion dollar program is coordinated by MIT and directed by Professor Roos. The Program draws on the resources of government, industry, and academia to develop new perspectives on this important world industry. A network of researchers from the seven dominant auto-producing countries, and from those having new and growing auto industries, is addressing issues that affect all aspects of this increasingly internationalized business. IMVP researchers are developing a view of the automobile industry as an interlocking system, in which technology, human resource management, international economics, and political conditions worldwide must be considered in the making of effective public and private policy.
In September 1986, the IMVP held its first Research Affiliates Meeting at Endicott House. An international group of researchers and observers from industry, government, and labor met to discuss the research agenda for the upcoming year. The IMVP work group developed a Work Plan which has guided the Program during 1986–1987. The Plan divides research into six areas. Each area focuses on a key element of the industry, and its contribution to the interlocking system comprising the entire industry. The six areas are: 1. The research and development process; 2. Supply systems; 3. Manufacturing practice; 4. Human resources; 5. Distribution systems; 6. The international system.

The first International Policy Forum was held in Niagara-on-the-Lake, Ontario in May 1987. At this meeting Research Affiliates presented the most important findings from a year of research pursued according to the 1986 Work Plan to a group of about 50 senior industry executives, government officials, and union leaders. The Forum provided an opportunity for these leaders to review and test the research findings with an emphasis on their policy implications for the future.

This year IMVP research has also contributed to the investigations of the MIT Commission on Industrial Productivity (CIP). Through the work of the IMVP and its predecessor programs, auto making, America's largest industry, has provided perhaps the largest and most complete body of research available for analyzing the complex phenomenon of productivity, particularly as it may be affected by foreign competition. Professor Roos is heading the CIP sector group on automobiles.

**International Competition in High Technology**

"International Competition in High Technology" is a project that has focused on US/Japanese competition in the semiconductor industry. International competition in high technology links technological progress, economic performance, and national security problems in novel combinations. The object of the current study is to consider rigorously the alternative policy objectives—and the instruments to implement them—the US might employ in enhancing its competitiveness in this area.

This project is being conducted by Carl Kaysen and Charles Ferguson who is completing a doctoral dissertation on US/Japanese competition in semiconductors and computers. The topic has attracted widespread concern on the part of industry and government; Mr. Ferguson recently testified before the Senate Judiciary Committee's Subcommittee on Technology and Law about the importance for the US of this strategically and economically critical industry. The project is sponsored by Motorola and the Semiconductor Research Corporation.

This project represents the high priority placed at the Center on understanding the forces that influence technological development in an era of international competition to determine what an appropriate and feasible balance is for the US in technological leadership, and to suggest mechanisms from national, state, and industry perspectives for the US to achieve its technological potential. Research in this area at CTPID is designed to:

*raise the level of national concern regarding the seriousness of the decline in US competitiveness and its implications for the economic vitality of the nation;

*identify reasonable and achievable expectations for US technological leadership while recognizing that international competition is fundamentally healthy and that transfer of technology to less developed countries is desirable; and

*understand what policies are necessary to foster, develop, and deploy technology that may enable the US to regain an appropriate technological position in the international community.

As are the research findings of the IMVP, the results of the current project on high technology are contributing to the work of the MIT Commission on Industrial Productivity. The industrial sector group studying semiconductors and computers is chaired by Professor Don P. Clausing (Electrical Engineering and Computer Science). Mr. Ferguson is serving as research associate for the group.

**MIT Commission on Industrial Productivity**

Many affiliates of the Center are involved in the MIT Commission on Industrial Productivity. Several CTPID programs concern the issues the Commission is addressing. The Commission is working to define the problems contributing to the widely perceived decline in US productivity. The objective of the group's work is to identify policy and practices, especially in education, that might offset this disturbing trend. Members of the Commission are using eight sectors of US industry to test their hypotheses about potential causes of the decline. In two of these sectors, motor vehicles and semiconductors and computers, the Center is supporting considerable research. (See above, International Motor Vehicle Program and International Competition in High Technology).
Research Program in Communications Policy

Members of the Research Program in Communications Policy (RPCP) are pursuing interdisciplinary research and analysis of communications issues involving the interaction of technology and policy. The program is led by Professor Russell Neuman (Department of Political Science). The RPCP is conducting several research projects including a two-year project supported by the Markle Foundation to carry out a program of research on future developments in American telecommunications. A recently completed study for the National Science Foundation is focused on the areas of communications standards, information technology, and industrial efficiency.

The program oversees the Audience Research Facility (ARF) located at the Liberty Tree Mall in Danvers. The facility recruits a demographically broad range of shoppers as study participants to conduct studies of audience responses to new developments in audio and video technologies. ARF combines the advantages of controlled laboratory conditions with access to samples of a size and diversity not usually available to survey researchers. Current projects include work on alternative measurement techniques for assessing how people respond to media technologies and tradeoffs among them, the role of audio in the perception of television, political learning from broadcast news, interactive media and High Definition Television.

These research projects are helping to develop new forms of data and new analytical tools to assist decision makers in reshaping the network structure.

RPCP research is conducted in cooperation with the Media Laboratory. Corporate sponsors include the Times-Mirror Co., International Communications Association, Bellcore, ABC, CBS, NBC, Time, Inc., the Washington Post Co., and a consortium of broadcast companies associated with the Center for Advanced Television Study.

The goal of the program is to maintain a critical mass of high quality education and research, to offer interdisciplinary training to some of the best young talent in the field and to add the viewpoint of independent and academically based scholarship to the public debate about issues of public communications. There are currently four faculty, five visiting scholars and research associates, 30 undergraduates (all UROP students) and 15 graduate students associated with the program.

Communications Forum

The Communications Forum links the Research Program on Communications Policy to the companies affiliated with the Industrial Liaison Program (ILP). The Forum's major activity is an annual series of seminars. Up to 10 meetings a year are designed to cover the full range of communications research at MIT. The scope of the Forum reflects the complexity and linkages within the field of communications. The speakers represent public and private sector interests as well as the research perspective. The presentations for Spring 1987 included "The Future of AM Broadcasting", "Open Network Architecture", and "Cultural Determinants of Technology".

Professor Kennedy (Department of Electrical Engineering and Computer Science) is director of the Forum. He is assisted by a Seminar Program Committee chaired by Professor Pierre Humblet. (Professor Peter Lemieux served as acting chairman during the Spring 1987 term while Professor Humblet was on sabbatical.) The Forum is supported by a portion of the ILP membership fees of companies sharing a special interest in communications policy and research.

Risk Assessment and Risk Management

Risk assessment and risk management are integral to the policy implications of many of the projects and programs in progress at the Center. Policy makers face an enormous challenge in trying to understand how risk assessment and risk management strategies should be integrated into decision making. MIT's strengths in science and technology can contribute greatly to these processes, but additional input from the social sciences is needed to broaden our understanding of how risks are perceived and how they can best be managed. Since its inception, the Center has promoted inquiry into the multifaceted interaction between technology and policy that in practice requires an understanding of risk. Research on hazardous substances and toxic waste management, environmental and occupational health, nuclear safety, and biotechnology are areas in which risks to human welfare must be considered.
Risk assessment and risk management were the topics of an Endicott House symposium sponsored by the Center in Fall 1986. The meeting was attended by 40 MIT faculty and research staff who are specifically interested in this area. At the symposium, they assessed the state of current research initiatives on risk at the Institute. The all-day meeting, moderated by Professor Susskind, brought together scholars and practitioners of risk assessment and management, including participants from the Boston Risk Assessment Group and the MIT Hazardous Substances Group. Synopses of the eight presentations forming the basis for discussion at the meeting have been collected in a proceedings, *Risk Assessment and Risk Management: A Perspective for Decision Makers*, available from the Center.

*Environmental Impact Assessment Review* for March 1987 is a special issue on risk assessment, risk management, and environmental decision making. While it appears obvious that risk assessment and risk management should be incorporated into environmental impact assessment (EIA), it is not always clear when or how they should be conducted or applied. The special issue includes five recommendations on how governmental agencies forced to make "risky decisions" should proceed. Major contributions to this issue were made by Professor Susskind, Senior Editor of the Review, Professor Merrie Klapp, a Center affiliate, and Steve Konkel, a doctoral student. The *Review* is a refereed quarterly edited at the Center.

This year, Dr. Dale Hattis has continued his work on improving quantitative risk assessment for chemicals posing a potential danger to health. His project on improving health risk assessment involves research into the use of pharmacokinetic models to improve carcinogenic health risk assessment and the effect of human interindividual variability on population risk from toxic chemicals. Such models should allow better assessment of the "biologically effective dose" of activated metabolites delivered to target tissues by different external exposure levels, routes, and time patterns of exposure. They should also permit more appropriate translation of dose units among species. Current work applies the model Dr. Hattis is developing to other related chemicals including ethylene oxide (a sterilizing agent used in hospitals) and butadiene (used in manufacturing rubber). Other pharmacokinetic modelling now being initiated will shed light on reproductive risks from glyco ethers, a widely used group of solvents used in paints and elsewhere. The project is supported by the US National Institute for Occupational Safety and Health.

**Technology and Law**

Technology and law are the focus of several Center research projects supervised by Professor Nicholas A. Ashford. One new project is an investigation of "The Adequacy of Tort Law and Insurance in Preventing and Compensating Damage from Exposure to Toxic Substances". With co-investigators Charles Caldart, Esq. and Dr. Hattis, Professor Ashford is gauging the strengths and weaknesses of both legislative mandates for compensating for environmental impairment and traditional common law remedies in tort. The second new project being pursued by Professor Ashford with the assistance of Mr. Caldart and Dr. Hattis addresses "Community Monitoring for Exposure to Toxic Substances: Scientific, Legal, and Ethical Concerns". This research will examine the scientific basis for determining exposures, and the legal and ethical problems concerning the communication of risks to the public. The project is sponsored by the Centers for Disease Control. The CDC and the EPA are required under new Superfund legislation to monitor and register potentially toxic substances and take appropriate actions to inform citizens about them.

Professor Ashford and Dr. Hattis are also continuing their work on "Policy Issues in Regulation of Toxic Substances". They are examining a variety of strategic and policy issues in the testing and regulation of toxic substances. This include the problems of small volume and new chemicals, maintenance of innovation, complex and variable chemical substances, biotechnology, multimedia initiatives, and state-federal relationships.

*Environmental Impact Assessment Review*

*Environmental Impact Assessment Review* is a quarterly journal highlighting approaches to impact assessment, environmental decision making, and the resolution of environmental disputes. EIA is an area in which technological and policy factors must be coordinated in a timely and publicly acceptable manner. The journal is designed to give planners, engineers, scientists, and administrators at all levels of the public and private sectors insight into the multiple problems and processes of environmental decision making.
The Review provides a forum in which practitioners and scholars can share what they are learning about EIA and dispute resolution. Three issues a year include feature articles on a wide range of topics and also summaries of new forecasting techniques and breakthroughs in environmental decision making organized under eight departments: Generating Alternative Policies, Programs and Designs; Impacts on the Natural Environment; Social Impact Assessment; Presenting Technical Information; Decision Making; NEPA: Theory and Practice; International Perspectives; and AGENDA for Environmental Negotiation. One issue annually addresses a single topic of special interest. The most recent (March 1987) was devoted to risk assessment, risk management, and environmental decision making. Many of the issues addressed in EIA Review are comparable and tangential to those being pursued by Center investigators. The Review became affiliated with CTPID in August 1986. The refereed quarterly is directed by Professor Susskind (Senior Editor), Editor Teresa Hill, and an International Advisory Board. It is published and distributed internationally by the Elsevier Science Publishing Co. Inc.

EDUCATION

Technology and Policy Program

The Technology and Policy Program (TPP) educates men and women for leadership on the technological issues confronting society. The main degree offered by the program is the Master of Science in Technology and Policy. With this diploma graduates can enter directly into practice in government and industry. The program also sponsors individual interdepartmental doctoral programs. These are designed for each student according to his or her particular interests. About one fifth of graduates choose to proceed to doctoral studies, and many do so at MIT.

TPP has now completed its first decade under the leadership of Professor de Neufville. There are now over 60 students in the program with a strong contingent of women and minorities (about 25 percent). The quality of the students is outstanding, as reflected by the large number of distinguished fellowships and awards they receive from outside sources. This year for example: Steven Farber was awarded the 1987 Alumni prize for Excellence and Leadership in Technology and Policy. Seth Hulkower and Stephen Korthals-Altes shared the 1987 Prize for Best Thesis in Technology and Policy. Seth Tuler, James Byrd, Peter Cebon, and Randi Zielinski were selected for the Alfred Keil Fellowship for the Wiser Uses of Science and Technology. Bryan Moser, a two-term Undergraduate Association President (UAP) was selected to receive the Hugh Hampton Young Fellowship.

The program received an in-depth evaluation of its first 10 years by an outside commission convened to help TPP formulate its future growth. This group was chaired by Dr. Arthur Gelb (MIT PhD '61) President and CEO of The Analytic Systems Corporation (TASC) and by Professor Marks. The core curriculum, consisting of the Prosminars, was substantially improved this year as part of a major effort to build upon past lessons. Professor Louis Bucciarelli, Leo Marx, and Richard de Neufville and Dr. Richard Tabor led this effort.

In the first full year of operation, the Center for Technology, Policy and Industrial Development has successfully begun the implementation of its extraordinarily ambitious goals in research and education. As a society, it is vital that we harness the enormous capabilities of science and technology and to develop better mechanisms to incorporate all relevant facts and opinions in the solution of science-and technology-intensive social problems. As many Center programs moved from the planning to implementation stage in 1986-87, new permanent staff members were added. These include Agnes Chow, Administrative Officer, Teresa Hill, Director of Publications, and John Ehrenfeld, Senior Research Associate. The number of researchers, research assistants, and support personnel fluctuate as new areas of investigation are opened, explored, and superseded by new projects. During this year, about 55 people actively contributed to new and ongoing work at CTPID. Working at the interface of technology and policy, Center researchers are addressing a widening range of these issues. This area of investigation presents new and exciting challenges every day, and we look forward to meeting them.

DANIEL ROOS
Introduction

Founded in 1973, the Center for Transportation Studies is an interdepartmental organization whose basic objective is to provide an environment in which faculty, students, and staff can work together on transportation issues, many of which are interdisciplinary in nature. It has the charter to coordinate transportation activities at the Institute and has developed programs of research, education and industry outreach. These programs are supported in part by income from the Center's endowment, which was graciously contributed by the UPS Foundation, and in part by support from industrial sponsors and from MIT.

MIT has a unique opportunity in the field of transportation, since it has faculty expertise in all the transportation modes (air, ocean, rail, auto, transit) and all the relevant disciplines (technology, planning, management and the social sciences) for dealing with transportation issues. The Center for Transportation Studies adopts a multimodal, multidisciplinary approach, building upon existing capabilities in the academic departments to address significant national and international transportation issues and problems.

The Center provides a context for transportation research and education activities at MIT involving faculty and staff members from 10 departments. The critical measure of the vitality of an interdepartmental center is its ability to involve faculty from a broad spectrum of the Institute. We are happy to report a broadening of our involvement with the Sloan School of Management faculty in areas such as information systems, operations research, applied economics, and labor relations, as well as a strengthening of our traditional ties in the School of Engineering, School of Humanities and Social Science, and the School of Architecture and Planning. About 50 faculty and staff participate in transportation activities at MIT.

Research

CTS has developed a broad agenda of research activities. The aim of the research program is to bring MIT's intellectual resources to bear on critical transportation problems in the public and private sectors. Areas of research include logistics and network analysis, rail and trucking operations, air transportation systems, computer systems, health and safety, ocean transportation systems, urban and regional transportation planning, labor issues, infrastructure maintenance and rehabilitation and transportation economics. A compendium of our research program entitled "Current Research Projects in Transportation at MIT" is available upon request from CTS.

This past year saw a very substantial increase in our research program, from both a financial and an intellectual viewpoint. Research volume exceeded $2 million in FY87, up from $0.7 million in FY86. The scope of our activities has expanded as we have worked to develop a number of new areas.

Logistics

Deregulation of the freight industry has enabled firms to take advantage of operations research methods and new computer technology to dramatically improve their logistical efficiency. It is estimated that distribution costs have dropped 20 percent since 1981, contributing to U.S. productivity and competitiveness. CTS faculty have been among the pioneers in developing practical, computer-based planning systems for logistics operations. These applications cut across the boundaries of industrial/transportation engineering and business systems. CTS currently is developing joint educational and research programs in logistics involving engineering and Sloan School faculty and students. CTS will continue to support the efforts of MIT faculty in these areas with Professor Yosef Sheffi in a leadership role. Professor Sheffi has ongoing research projects in a number of areas including logistics network analysis methods, and optimal equipment positioning and routing. Expanded relationships with the faculty of the Operations Research Center, now under the joint direction of Professor Thomas Magnanti and Professor Amedeo Odoni, both long time participants in CTS, will greatly help our logistics program as will the addition of Dr. Harilaos Koutsopoulos to the faculty of the Department of Civil Engineering.
Information Systems

The computer and information systems revolution has had and will continue to have a profound effect on the transportation field. To position ourselves effectively in this area, we funded three seed research proposals this year noted below.

Another initiative is the development of a research program in the design and implementation of large scale, distributed heterogeneous computer systems. CTS has successfully joined faculty and staff (Professor Stuart Madnick, Dr. Amar Gupta, and others) of the Sloan School of Management with the appropriate people at the Transportation Systems Center (TSC) of the U.S. Department of Transportation and Wright Patterson AFB. This project represents a major broadening of the research agenda of CTS in an area of great potential importance to the transportation industry.

Transportation Technology

CTS anticipates a greater emphasis on transportation technology as we utilize our relations with government and industrial sponsors to help technology oriented faculty develop research funding. An example is CTS's seed research support of Professor Tomasz Wierzbicki in the crashworthiness area. This seed support has allowed him to develop an industry funded research program being carried out within the CTS framework.

We see Professor Wierzbicki's effort as part of an added emphasis in transportation safety. As a long term effort, CTS will address the question of transportation safety from a technological as well as a system viewpoint. In addition to Professor Wierzbicki's work, we have activities in intersection safety (Professor Moshe Ben-Akiva) structural integrity (Professor Frank McClintock and Professor Reggie Pelloux) and the relation of transportation safety to deregulation (Professor Nancy Rose, who received seed research funding last year from CTS for her project).

Another initiative involves various projects concerned with the physical systems side of railroading, in areas such as rail car performance (Professors Karl Hedrick and David Wormley) and track performance (Professors Joseph Sussman and Sue McNeil, and Carl Martland).

Infrastructure Redevelopment

Transportation infrastructure represents a major fraction of civil infrastructure in the U.S. and worldwide. The decay of this national asset is well documented. CTS is developing research programs in support of the national efforts to address this issue.

One such program is the New England Transportation Infrastructure Consortium, managed by Thomas Humphrey, which combines the resources of various State Departments of Transportation, state universities and MIT to pursue the development of a substantive research agenda in areas such as bridge deck deterioration (Dr. Ken Maser) and trucking regulation (Mr. Humphrey).

Further, CTS is focusing on infrastructure issues as a participant in the Center for Construction Research and Education/Army Research Office project, a new multi-million dollar research program at MIT. In particular, the CTS contribution will deal with the implications of new technologies in the management, monitoring and control of large scale transportation infrastructure systems. Professor McNeil and Michael Markow are the primary participants in this activity.

Seed Research

CTS has a seed research fund which permits faculty and staff members to develop new and innovative research ideas. This past year, support was made available for the following five programs:

Professor Richard de Neufville: Geographic Database Management for Routing and Zoning of Delivery Services
Professor Sue McNeil and Carl Martland: Applications of Knowledge Based Expert Systems to Transportation
Professor Amedeo Odoni: Computer-Aided Design of Large Airport Passenger Terminals
Professor Harilaos Psaraftis: Specially Structured Routing and Scheduling With Time Windows
Professor Nigel Wilson: Mitigating the Congestion Impacts of New Central City Development

We see each of these programs representing important thrusts for CTS.
Educational Program

CTS contributes to the educational program of the Institute in several ways. Through our extensive research program, CTS provides exciting assignments for a number of students (as well as financial support). Students from various engineering departments, economics, urban planning, management, mathematics, and the Operations Research Center were involved in transportation research this past year.

CTS also sponsors the Master of Science in Transportation (MST) degree, an interdepartmental degree program for graduate students primarily interested in the transportation field. This program is chaired by Professor Nigel Wilson. Graduates of this program continue to be in great demand in both the public sector and the private sector. During this past year, CTS began a comprehensive study of the MST degree and its appropriate role here at MIT. We will continue to work toward improving this degree program.

CTS continues to support transportation related programs in a variety of departments including Civil Engineering, Mechanical Engineering, Ocean Engineering, Aeronautics and Astronautics, and Urban Studies and Planning. During this past year, a subject in transportation logistics was offered to 20 Sloan School of Management students, thereby exposing them to important concepts in the management of transportation systems. The development of this subject by Professor Sheffi (Civil Engineering) and Professor Steven Graves (Sloan School of Management) was supported by CTS.

In all, CTS provides substantial transportation education opportunities for students in a variety of programs at the Institute.

CTS continued to offer short summer subjects for the transportation community. Subjects in 1) Logistics Analysis 2) Transit Management and 3) Discrete Choice Analysis were offered.

United Parcel Service (UPS) Fellowships

CTS continues to provide fellowship support for particularly able students at the MST and doctoral levels funded by the UPS Foundation. Each year we have seen a growth in the number of doctoral fellowship applications. In 1986/87, we received eight applications and we split the award between Mr. David Geltner and Ms. Cynthia Barnhart. For 1987/88, we received thirteen applications, and again split the award between Paul Thompson and Scott Smith, and granted a special summer fellowship to Brian Cromwell.

In addition, we awarded partial fellowships to two particularly able MST students for 1986/87, Martin Liss and Rina Rotshild. For 1987/88, MST fellowships were awarded to Mark Hickman and Ibrahim El Sanhouri. Further, we continued to provide partial support for needy graduate students in transportation.

Affiliate Activities

The Affiliates Program, under the direction of Gerard McCullough, Deputy Director of CTS, is an important element in the educational and research programs of the Center. It also adds a public service dimension to transportation activities at MIT.

The Program was established in 1981 with the aim of encouraging contacts between MIT faculty and organizations involved in private sector transportation. Membership in the Affiliates has grown to 16 firms and includes the country's strongest shippers and carriers. Members include Burlington Northern, CSX Transportation, Digital Equipment Corporation, Dupont, General Motors Research Labs, Gillette, IBM, IU International, 3M, North American Van Lines, Rockwell International, Ryder, Sea-Land, Southern Pacific, Union Pacific, and UPS. Much of the growth in the program has come from shipper organizations eager to use computer-based planning techniques and innovative technology to take advantage of a new transportation environment created by deregulation. Faculty at CTS have developed research relationships with a number of affiliates including UPS, Gillette, Burlington Northern, IU International, and North American Van Lines.
Educational activities of the Affiliates Program include several technical seminars a year which focus on topics of mutual interest to Affiliate staff and MIT faculty members. In April the Affiliates Program sponsored a highly successful two day course on mathematical programming for Affiliates. In the summer CTS conducts an Executive Program in Transportation devoted to developing a common set of analytic techniques to be used by carriers and shippers in the new freight markets. The Affiliates Program also has played a role in student education by providing summer employment (and long term employment) opportunities for MIT transportation students.

Each year one of the Affiliate firms sponsors the annual Affiliate Meeting at a working site which combines logistics demonstrations with lectures by MIT staff and Affiliate staff. This past year, the host was 3M. CSX will be host for next year's meeting which will take place aboard a freight train bound from Baltimore to Philadelphia.

CTS Forums

The CTS Forums are off-the-record meetings held primarily at Endicott House which have given faculty and research staff access to transportation decision makers at the highest levels. The Forum also have given these decision-makers an opportunity to meet with MIT researchers and to work with each other at a time when transportation markets are changing dramatically. This mutual interaction has given MIT an opportunity to provide a significant public service by helping to shape an agenda of issues for transportation decision-makers in the coming decade. The CTS Forum series was inaugurated at MIT Endicott House in June 1985 and was continued with additional forums in January and September 1986.

The format of these meetings was straightforward. Thirty decision-makers, usually the CEO's of carriers and the VP's for logistics of shippers, were invited to spend two days with MIT faculty and top government officials discussing transportation issues. The issues were a) changing relations between carriers and customers b) changing labor and management responsibilities, and c) changing public and private responsibilities. The groups devoted a half day to each of these topics.

Those three initial forums served to highlight a number of critical areas in transportation especially those whose resolution requires a high degree of cooperation among transportation providers and users as well as government agencies. Participants have recommended that MIT continue to address these problems by playing a "convocacy" role and by focusing individual forums on specific transportation issues.

In October, 1987 CTS will host a forum at Endicott House devoted to exploring the changing relationship between transportation labor and transportation management. This forum builds on a substantial research program developed by Professor Robert McKersie. In February 1988, a forum at Endicott House will be devoted to long run solutions to the problem of airport congestion. This forum builds on an extensive set of research projects in the air arena conducted by Professor Robert Simpson and Professor Odoni. It is anticipated that CTS will continue the forums on an annual basis.

The Transportation Computing Lab (TCL)

The Center formally established a Transportation Computing Laboratory three years ago to serve as a focal point for academic and research computing activities. Several new initiatives are underway in computing in CTS, made possible by the generous support of the UPS Foundation. Professor Sheffi directs this facility.

This academic year saw the continued evolution and strengthening of the TCL. This year we added two MacIntosh personal computers, an Apple printer, and two PC Limited Turbo AT II workstations. In addition, we have both acquired and developed a large amount of software for the personal computers and in particular for the Microvax computers. We now have two Microvax computers, one serving the CTS network and the other serving as the above mentioned stand-alone workstation.

The usage of the TCL has increased steadily during 1986/87 and we are now at the point of reaching capacity. The most pressing of the capacity issues is the Vax workstation. We also reached capacity on the usage of the personal computers (of which we have 12). To relieve the pressure there we had to regulate word processing and institute a system of priority usage.

The heavy usage of the facility is, of course, a sign that the facility does its job in serving the CTS community. It serves the transportation student body for both academic and sponsored research work. All the computer work in transportation and logistics courses is performed in the TCL.

We plan to continue to expand this popular facility and will continue to seek innovative ways to service TCL's academic and research constituency.
Seminars and Special Events

CTS sponsored a seminar series which brought many interesting speakers to the campus. These seminars represented both the public and private sector interests of CTS and were well attended by the faculty and students of the Institute as well as many people from the local transportation community.

Also, the AAR Affiliated Laboratory at CTS was a co-sponsor (along with the Association of American Railroads, Railroad Personnel Association, and National Railway Labor Conference) of a major conference on "Technology, People and Productivity in the Railroad Industry" held in Boston. About 250 people attended.

Advisory Committee Meeting

The Center has an external Advisory Committee which meets periodically to review the Center's program and advise the Center on future courses of action. The Advisory Committee, comprised of distinguished transportation leaders from the private and public sectors reports to the Dean of Engineering. On April 8 and 9, 1987, the committee met to review the activities of CTS. Attention was focused on the research, education and industry outreach programs of the Center and dealt with many of the programs discussed in this report.

The committee was supportive of our initiatives and provided us with many new ideas to pursue. The expected substantial increase in the demand for transportation professionals was noted at the meeting, as were the tremendous opportunities facing the research community resulting from deregulation. Our thanks go to all the members of the committee for their important inputs to our programs.

The committee is chaired by Denman K. McNear, Chairman, Southern Pacific. Other members are Larry P. Breakiron, Senior Vice President, United Parcel Service; William Coleman, O'Melvey and Meyers; Thomas B. Deen, Executive Director, Transportation Research Board; Robert Fahey, Senior Vice President, Sea-Land Corporation; Francis B. Francois, Executive Director, American Association of State Highway Transportation Officials; Darius Gaskins, President and Chief Executive Officer, Burlington Northern Railroad; Robert Kiley, Chairman, Metropolitan Transit Authority; Roy Mayeske, Executive Director/Transportation, 3M; Frank Nageotte, President, Greyhound Corporation; Craig Philip, Vice President-Strategic Planning, Ingram Barge Company; Laurence A. Pierce, First Vice President, The First National Bank of Boston; George E. Powell III, Senior Vice President-Operations and Sales, Yellow Freight System; Clifford M. Sayre, Director-Logistics, DuPont; William Sharkey, Jr., Director-Spares Program Management, U.S. Department of Defense; William K. Smith, Consultant; Professor Richard Soberman, Head of Joint Transportation Program, University of Toronto; and W. Gerald Wilson, President, International Road Federation.

The advent of new technologies, the impact of deregulation and the continuing emphasis on international competition all contribute to a challenging transportation environment. We at the Center are pleased to be involved in such a vital and dynamic field and we look forward to helping advance transportation systems into the next century.

JOSEPH M. SUSSMAN
The MIT Laboratory for Computer Science (LCS) is an interdepartmental laboratory whose principal goal is research in computer science and engineering.

Founded in 1963 as Project MAC (for Multiple Access Computer and Machine Aided Cognition), the Laboratory developed the Compatible Time Sharing System (CTSS), one of the first time shared systems in the world, and Multics -- an improved time shared system that introduced several new concepts. These two major developments stimulated research activities in the application of on-line computing to such diverse disciplines as engineering, architecture, mathematics, biology, medicine, and management. Since that time, the Laboratory's pursuits expanded, leading to pioneering research in knowledge based (expert systems), computer networks and public cryptography. Today, the Laboratory's research spans a broad front of activities, grouped in four major areas.

The first such area, entitled Knowledge Based Systems, involves making programs more intelligent by capturing, representing, and using knowledge which is specific to a narrow problem domain. The Laboratory's Clinical Decision Making Group uses expert medical knowledge for computer-assisted diagnosis.

Research in the second and largest area entitled Machines, Languages, and Systems strives to discover and understand computing systems at both the hardware and software levels that open new application areas and/or effect sizable improvements in their ease of utilization and cost effectiveness. A large part of the Laboratory is involved in the architecture of large multiprocessor systems (which tackle a single task, e.g., speech understanding or weather analysis) by the Computation Structures, Real Time Systems, Information Mechanics, and Parallel Programming Research Groups. Continuing research includes the analysis and synthesis of languages and operating systems for use in large geographically distributed systems by the Distributed Systems and Programming Methodology Groups. Finally, a key application involving distributed databases and community information is pursued by the Programming Systems Research Group.

The Laboratory's third principal area of research, entitled Theory, involves exploration and development of theoretical foundations in computer science. For example, the Theory of Computation Group strives to understand ultimate limits in space and time associated with various classes of algorithms; the semantics of programming languages, from both analytical and synthetic viewpoints; the logic of programs; the utility of randomness in computation; concurrent computation and the links between mathematics; and the privacy/authentication of computer-to-computer messages. Other examples of theoretical work involve the study of distributed systems by the Theory of Distributed Systems Research Group, and the development of effective algorithms for VLSI design.

The fourth area of research entitled Computers and People, is concerned with the interrelationships between people and machines -- for example, the societal impact of computers carried out by the Societal Implications Research Group.

Some of the year's research highlights were as follows:

The Multiprocessor Emulation Facility (Professor Arvind) and the Laboratory's Simulators were used to study the feasibility of a Tagged-Token Dataflow architecture. The results of these and related studies have led us to the design of a one gigaflops (peak performance) 256-processor machine which we are currently proposing (to DARPA) for construction. A comprehensive software system, Id World, has been documented and released. It translates functional programs from the language Id to representations that can be emulated on the above facility, simulated on an IBM 4381 computer, or executed on a dataflow machine. This programming environment will be used to study and assess additional application areas.

In the same area of multiprocessor systems, we are continuing our research on: Project L (Professor Stephen Ward) and CAM-7 (Dr. Tommaso Toffoli). L is a new model of computation characterized by: (1) a large collection of finite state machines and state representations with the property that programs written in object-oriented languages (with concurrency) can be efficiently compiled into L structures, and (2) L structures can be efficiently executed on a proposed hardware architecture associated with the L project. The CAM-7 architecture is a highly parallel cellular automata machine that further extends our previous architectures in this area. This machine will be able to update in one screen refresh interval, half-a-billion digital cells which are configured either as a cube or as a plane.
During the year, a good deal of progress was achieved in designing and defining the LCS Common System, now named Mercury, which is aimed at facilitating the composition of programs across different computational environments. For example, a program written in a Lisp Machine environment should be able to call a subprogram written in C under a Unix environment.

During the same period we were successful in funding (through Siemens) and formally initiating research on learning systems. This program strives to develop theories and machines that can learn from their environments, and not from their programmers. We believe that the rapid technological progress in architectures and VLSI calls for a re-examination of learning theories and approaches. In the theoretical area, we have developed (Professor Baruch Awerbuch) an approach that can make network protocols run reliably on unreliable networks, and we have established (Professor F. Thomas Leighton) some important results about broadcast networks.

Two of the Laboratory's past accomplishments have achieved higher levels of standardization. First, the Nubus standard (Professor Ward) was adopted by Apple Computer for their new open architecture systems, starting with the Apple II GS. Second, the X-standard (Mr. Robert Scheifler) for graphics has been adopted by the MIT School of Engineering's Project Athena and some 20 companies which are urging us to form a consortium for the continued development of X.

During 1986-1987, the Laboratory has continued its successful Distinguished Lecturer Series with presentations by Carnegie Mellon University's Hans J. Berliner; Cal Tech's Charles Seitz; Robert E. Kahn, President of the Corporation for National Research Initiatives; David J. Kuck, Director of the Center for Supercomputing Development at the University of Illinois; Leslie B. Lamport from DEC's Systems Research Center; and Nils J. Nilsson, Chairman of the Computer Science Department at Stanford University.

The Laboratory had several personnel changes over the past year including: the return of Mr. Albert Vezza as Associate Director, the arrival of Dr. Thomas Greene as Director of Computing Resource Services and the departures of Dr. Irene Grief to Lotus Corporation, Dr. Gerard Vichniac to MIT's Plasma Fusion Center, and Professor Richard Zippel to Symbolics, Inc. Other changes included the promotions of Drs. Toffoli and William Long to Principal Research Associate, and Professors David Gifford and Shafi Goldwasser to Associate Professor.

Our Laboratory consisted of 320 members -- 45 faculty and academic research staff, 30 visitors and visiting faculty, 60 professional and support staff, 110 graduate and 75 undergraduate students -- organized into 14 research groups. Laboratory research during 1986-87 was funded by 12 governmental and industrial organizations, of which the Defense Advanced Research Projects Agency of the Department of Defense provided over half of the total research funds. Also during the same period the Laboratory employed 23 undergraduates through the "Hacker Heaven" project which strives to identify promising potential researchers in Computer Science.

Technical results of our research in 1986-87 were disseminated through publications in the technical literature, through Technical Reports (TR 367-TR 394), and through Technical Memoranda (TM 296-TM 332).

MICHAEL L. DERTOUZOS
The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 15 faculty and 10 research staff from the departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented included power electronics, automatic control, electromagnetics, continuum electromechanics, high voltage research, heat transfer, insulation research, quantitative physiology, cell biology, systems analysis, and economics. Faculty and students collaborate in projects aimed at both the practical engineering objectives of sponsors and at the underlying engineering sciences. Interactions with other laboratories is encouraged, including the Energy Laboratory Electric Utilities Program.

Power Electronics

Power electronics research is led by Profs. J.G. Kassakian, M.F. Schlecht, G.C. Verghese, and D. Otten. The focus continues to be the technology development for using r.f. switching to create small, component-like power supplies. These micro-supplies are seen as leading the next revolution in power supply architectures for computers and in automotive power distribution systems. Several developments will help make very high power density, very mass-producible power supplies for electronic equipment. These are:

1. The detailed understanding of how parasitic inductors and capacitors influence the operation and efficiency of standard power circuit topologies. From this understanding we have been able to show how one such topology has very important advantages compared to those pursued elsewhere when operated in the 10 MHz range. We have also been able to point toward the specific improvements in components and fabrication techniques that would be of greatest, and most universal, value.

2. New power MOSFET structures that can efficiently operate at 10 MHz. This work used the very high resolution capabilities of the Microsystems Technology Laboratories to build components with very small parasitic capacitances compared to today's commercially available devices. We have also developed an integral gate driver that avoids the parasitic inductance of an external connection and have found a way to develop a synchronous rectifier whose parasitic body diode has a reverse-recovery time of less than 1 ns.

3. Magnetic structures that will result in small, efficient, and mass-producible transformers suitable for 10 MHz operation. This work involves the use of numerical simulation to determine skin and proximity effects on the distribution of current in the windings, the characterization of both hysteretic losses and permeability as a function of flux level and frequency for Ni-Zn ferrites, the tradeoff between copper and core losses to find an optimal design, and the development of multi-layer copper-polyimide windings that give repeatable leakage inductance and resistance values.

4. Active filters that provide the strict filtering requirements imposed on 1-10 MHz converters by the FCC and VDE agencies. This work involves the design and construction of linear amplifier circuits that effectively make inductors and capacitors appear 500 times larger than they really are at 1 MHz. The saving in actual energy storage, and therefore the size and cost, of the components, is proportionally reduced.

The concept of the parity simulator has been extended to nuclear reactor problems. In a collaboration with the Energy Lab (Prof. Kent Hansen) a demonstration simulator for a nuclear reactor was built and is being evaluated. The initial project provides for a 1-dimensional simulation of the reactor and divides the reactor core into 4 segments. The simulator runs in real time but could possibly be modified to run faster that real time. This reactor model could eventually be connected to parity-simulator-like models for the pipes, pumps, and heat exchangers that are concurrently being developed.

Professor John Kassakian received the 1987 William E. Newell Power Electronics Award, presented annually by the Power Electronics Council for "outstanding achievement in power electronics". He presently serves as the President of the IEEE Power Electronics Council. LEES personnel have been key players in the organization of the IEEE Power Electronics Society (PELS).
The efforts of an informal group of students, faculty, and staff, led by Mr. David Otten, to build a "world class MicroMouse" have met with success. The latest mouse, MITEE Mouse II, received first place at the IEE 1987 World Final in London. Unfortunately, the real competition, the Japanese were not there. We do have a benchmark maze which the Japanese used in 1985 when their best time through the maze was 20 seconds. Our best time to date is only 28 seconds, however, the previous best non-Japanese entry was the mouse we beat in London (Enterprize) which took 40 seconds. The rules for the IEE contest emphasize independence and good maze solving ability in addition to raw speed so it may have been possible for us to come very close to them with the British scoring system even though we do not have the raw speed. This project hones the interdisciplinary and collaborative skills of the laboratory.

The MIT/Industry Power Electronics Collegium continues to be a source of support and guidance for the power electronics activities. A workshop on Manufacturing Issues was held for Collegium members this spring. Through the development of an MIT graduate subject and a summer course for industry, power electronics research has a strong influence on graduate and continuing education.

Systems Identification and Control

Profs. Lang, Thornton and Verghese, and Dr. Umans and their students continue to expand their research on the analysis, design, estimation and control of electromechanical systems. Variable-speed drives based on a variety of rotating machines, having wide industrial, commercial and residential application, are the primary, but not exclusive, focus of this research. While there is some governmental support for this research, the majority of the support is industrial. With increasing frequency, the industrial sponsors are becoming close partners in the research, and are in the process of incorporating the results into their products. This research is also providing material for several undergraduate and graduate classes.

The integrated character of this research is an important characteristic. The electromechanical systems include actuators, sensors, power electronics, digital controllers, and control and estimation algorithms, operating together to provide accurate, efficient and reliable energy conversion. This research focuses as much on the interactions of the system components as it does on the components themselves. Consequently, significant advances have been made in an area that might otherwise be considered mature. Among the advances are the following:

1. A 60-kW drive based on the variable reluctance motor (VRM) has been developed for electric vehicle propulsion. In so doing, we have developed a fundamental understanding of the nonlinear electromechanical dynamics of this drive, and we have introduced the motor currents into the development process as a design variable. The integrated approach to its development yields a drive with low cost, high reliability and highly competitive specific torque and power. This system is now undergoing high-power tests. As a result of this research, we have received considerable industrial interest in VRM-based drives for other applications.

2. A VRM-based drive has been developed which provides a very high specific torque. This drive is suitable for robotic and many other manufacturing applications. The controller in this drive, which is itself highly nonlinear, appears to regulate a smooth torque at all speeds, which is essential for the motivating applications. Again, the integrated approach to the development of this drive is key. This drive is now under commercialization.

3. A 5-kW VRM-based drive has been developed for appliance-type applications such as compressors. Here, low cost and high efficiency are important. Again, our significant contributions are in the understanding and development of the motor and its controller. Additionally, we have added a filter to the controller which estimates rotor position from information in the motor voltages and currents. This eliminates the need for explicit position sensors, and thereby reduces the cost of the drive. This filter has received considerable industrial interest independent of the motivating application.

4. We have extended the estimation of rotor position using information in electrical variables from the VRM to the permanent-magnet and induction motors, other very popular motors. The appropriate nonlinear filters have been developed, and are at various stages of experimental testing. Based on experience with the VRM, estimation accuracies on the order of 1 part in 30,000 to 60,000 of a revolution are anticipated. This is more than
sufficient for propulsion and appliance applications, and also sufficient for many robotic and manufacturing applications. In short, this research has produced an understanding of electromechanical actuators as simultaneous accurate sensors of the motion which they actuate.

Related to the estimation work for electromechanical systems, Profs. Lang, and Verghese and their students have developed a means of estimating parasitic components within power electronic devices and circuits based on the information in peripheral high-power signals. The values of these components are important to the operation of the device or circuit, but are rarely measurable directly. Thus, this estimation process provides a valuable tool in the analysis and evaluation of power electronic devices and circuits.

Another initiative in the area of electromechanical systems is the development of micromotors systems. This work is the product of Profs. Lang, Schlecht, and Howe and their students. Micromotors are very small motors, on the order of one hundred microns diameter, which are surface machined from silicon. We will shortly have our first test version of a motor, perhaps within a month.

Prof. Lang and his students continue to pursue the development of special-purpose processors for general control applications. Currently, they are studying the effects of soft failures in these processors in an effort to ultimately design more robust and reliable processors for critical applications. Recent accomplishments include the development of a simple means to model the stochastic failure process at the device and small-scale-circuit levels.

Prof. Lang and his students recently completed the development of state and parameter estimators for flexible systems such as large space structures. The important characteristic of these estimators is that they remain stable in the presence of unexpected noise and mild nonlinearities. Further, the estimation biases caused by these phenomena are easily analyzed leaving the user with useful bounds on estimation errors. If the nonlinearities are anticipated prior to estimation, they too can be estimated.

Electromechanics, Heat-transfer, and Cryogenics

The Superconducting Generator, project involving Profs. G.L. Wilson, J.L. Smith, J.L. Kirtley, Dr. S. D. Uman and Mr. W. H. Hagnan has some history at MIT, having been started about two decades ago. Our third experimental machine, rated at 10 MVA, has recently undergone a series of thermal and electrical tests. Electrically, the machine matches our expectations. Fundamental voltage and current are close to predicted values, and circulating harmonic currents are low. The machine is yielding important information, although its thermal performance seems to be somewhat inferior to expectations. We are evaluating this performance at the present time. Recent developments in condensed matter physics seem to indicate the possibility of superconductors with substantially higher transition temperatures than those which we have been using. If such conductors become practical (here, practical means having substantial current densities at reasonable field strengths), they will have real impact on the types of machines we have been designing. As it turns out, the machine designs are not likely to change very much, but their economics will become much more attractive.

Continuum Electromechanics

Using the "imposed omega-k"approach to dielectrometry, Prof. Melcher and his students have developed an apparatus and technique for measurement of distributions of complex permittivity. A spatially periodic field is imposed on a material by means of a pair of interdigitated electrodes at the material surface. The same electrodes are used to measure the effect of the material on the current induced in the electrodes in response to this field. The spatial frequency response (a function of the dominant wavenumber, k, imposed by means of the electrode structure) is used to deduce the spatial distribution of complex permittivity when that property depends only on the coordinate perpendicular to the electrode structure. Because the deduction can be made without recourse to the temporal frequency response, the complex permittivity distribution can be deduced as a function of temporal frequency. This technique is currently part of an ongoing experimental effort to use dielectrometry for parameter estimation purposes. The technique is currently being developed commercially for the resolution of water distributions in salt-water ice.

In a utilities sponsored project co-supervised by J.R. Melcher and M. Zahn, electrokinetic effects on flow electrification of transformer oil in power transformers is being studied. Electrification in systems where flowing highly
insulating liquids may also function to insulate and cool equipment is being recognized as a problem in applications that range from power apparatus to automotive fuel delivery systems. Static charge build-up in transformers due to the flow of transformer insulating oil is leading to electrical breakdown failures. A compact laboratory apparatus has been developed that provides measurement of properties needed to predict charge generated by a transformer oil/cellulosic interface under both equilibrium (i.e. no current flows across the interface) and non-equilibrium conditions. In this apparatus application of an external field simulates the effects of transformer energization and produces non-equilibrium currents, which give rise to charges that are compared to those predicted by a model developed in this work. This migration-based model predicts the effect of external field strength and frequency, as well as flow conditions, on the injection of charge from the boundary into the turbulent flow core.

Experimental data displays energization currents which have dependencies on frequency, Reynold's number and voltage sufficiently like those predicted to encourage refinement of the injection model to include the effects of what turbulent diffusion there is inside the "laminar sub-layer".

**High Voltage and Insulation Research**

The project "Trend Analysis: Performance Monitoring of Transformers" (sponsored by eight electric utilities and carried out in collaboration with the Energy Laboratory Electric Utilities Program) has progressed from a diverse group of bench-top laboratory experiments to on-line monitoring of a loaded, 50 kVA transformer. The goal of this project is to detect changes in transformer operation, diagnose the consequences of the detected changes, and notify the operator of incipient failures in time for corrective action to be taken. Six aspects of transformer operation are sensed on-line. These sensed quantities include: Electrical Terminal Variables, Temperatures, Vibrations, Oil Water Content, Oil Dielectric Properties, and Partial Discharges. Current work is devoted to development of adaptive software models which predict 'normal' transformer operation, thereby allowing data collected from the transformer to be compared with expected readings in real time, leading to the early detection of deviations from nominal operation.

The transformer monitoring program is managed by Dr. C. Cooke, who also is responsible for diagnostics involving partial discharges where results have been obtained that correlate discharge signatures with specific insulation degradation processes. Prof. Kirtley has focused on monitoring vibrations of the winding, caused by excitations from the core (responsive to voltage) as well as from the winding (responsive to load current). With his students he has developed a "black box" type model which appears to be able to match vibrations during normal operation, and indicate divergent operation with structural changes which have been intentionally introduced. Temperature has been shown to be a critical factor in vibrational analysis and that has necessitated compensation for temperature. This has been accomplished for small ranges of variation. It seems reasonable that larger ranges can be accommodated. Eventually, Kirtley expects to be able to monitor transformer structures using vibrations in the acoustic frequency range.

Prof. Zahn and his students continue to be concerned with non-invasive electro-optic measurements of the electric field stressed materials. The motivation of this work is to understand electrical conduction and charge transport phenomena in order to reduce losses and raise the electrical breakdown strength of electric power apparatus. This year we have improved the sensitivity of the measurement technique to perform measurements in polymers and sulfur hexafluoride (SF$_6$), typical "workhorse" materials used as high voltage insulation. This is the first time such measurements have been made in these materials at high field levels used in practice.

In a project conducted with K.A. Wright and C.M. Cooke, Zahn has documented the effects of electron beam energy and current density on electron penetration into polymethylmethacrylate (PMMA) to generate peak fields up to 3.5 MV/cm. This work is being compared to existing models to better understand the physics of the charge trapping, conduction, relaxation, and electrical breakdown mechanisms in solids. Particular motivation is to understand the "electrical tree" discharge patterns often found in solids, especially for power cables. Videotapes of the charging and discharging process provide a complete history of the electric field build-up and collapse.

Because of the aesthetic nature of the optical patterns, Prof. Zahn and his students were one of ten winners in the January, 1987, "Great MIT Image Making Contest". This contest concerned the generation of artistic images by technological means.
Complementary work has also proceeded in high voltage stressed (≈50 kV/cm) PMMA, for the first time showing positive charge injection into PMMA using copper electrodes and measuring the charge mobility using open circuit decay. They are presently examining other metal electrode materials such as aluminum, brass, and stainless steel to find a negative charge injecting electrode into PMMA. With double injection they have found an increase in voltage breakdown strength due to space charge shielding lowering the electric field at both electrodes.

Prof. Zahn and his students have also demonstrated the optical measurement technique in high voltage stressed SF6, particularly showing how charge trapping in a PMMA spacer can give rise to high electric fields in the SF6 long after high voltage has been removed. This has direct application to understanding spark discharges along gas-insulated high voltage bushings.

In related insulation work by Dr. C. Cooke, accumulation in dielectrics is also being studied. However, here a new means to observe volume charges is based on electro-acoustic transduction. In this method, the charge magnitude and distribution is converted to a corresponding pressure distribution which propagates to the sample surface where it is converted to an electrical waveform. Signal processing with a repetitive drive has been shown to allow this method to be sensitive in detecting relatively weak signals from charges as low as 1 nC/cm³. Applications for this work that are being pursued include medical electron beam dosimetry, jointly with Mr. Kenneth Wright, and high voltage cable charging. Dr. C. Cooke's work on insulation has included studies of metallized thin polymer films used for capacitors in motors and lighting. The polymer films, typically several micro meter thick, are subject to degradation and failure. By design, once dielectric failure occurs, the film is made self-healing by virtue of the thin metallized layer which erodes and 'clears' the conducting path during the breakdown event. The studies have identified microdischarges in small gaps between film layers as being a major contributor to degradation. Nanosecond diagnostics are being used to quantify the energy flow during the bulk discharge period. The goal of this work is to identify the fundamental causes for degradation and means to slow the process so that higher stress, lower cost more efficient capacitors can be made.

**Biological Electromechanics and Physiology**

Professor Grodzinsky and his group are studying the influence of electromechanical interactions in the normal health and pathological degeneration of connective tissues. A recent series of experimental and theoretical discoveries resulted in the awarding of the Borelli Prize of the American Society of Biomechanics (to Prof. Grodzinsky and two recent doctoral students; Eliot H. Frank and Sol R. Eisenberg) for "exemplary research in the field of biomechanics, and "significant advances in the field of articular cartilage and connective tissue electromechanics." Recent discoveries have also included the finding that physiologic compression of cartilage appears to significantly alter cell synthesis of cartilage matrix molecules in a manner linked to compression-induced changes in cartilage fixed charge density. Specific chemical extraction of matrix charge groups altered cell synthesis in a manner that mimicked the effect of mechanical compression.

The altered cellular response would also change the ability of cartilage to produce compression-induced streaming currents, another possible feedback mechanism between the tissue's physical (electromechanical) properties and its biological behavior. These discoveries in living cartilage maintained in organ culture may aid in the understanding of how to initiate repair (cell synthesis) processes in disease states such as osteoarthritis.

In another series of studies, both theoretical and experimental techniques are being used to assess the physical mechanisms by which applied electromagnetic fields may interact with biological tissues. Electric field strengths induced inside the body by radiofrequency fields within the ANSI Standards were estimated to be capable of slightly altering cell transmembrane potential. Independent engineering dosimetry studies by others also pointed to this frequency regime, which is important due to many industrial exposure conditions; the ANSI standards for exposure limits in this frequency range are now under revision. Experiments in our laboratory have now shown that current densities as high as 30 mA/cm² do not appear to cause cartilage cells to synthesize special "stress response proteins" common to toxic (e.g., chemical or thermal) exposures. However, the level of total protein synthesis appears to increase with current density. For the second time, this work resulted in the Curtis Johnson Memorial Award to Ph.D. candidate Laura MacGinitie by the Bioelectromagnetics Society for the best Student Paper presented at the international conference in June, 1987.
Prof. Grodzinsky is also continuing research on electrical and chemical control of the permeability properties of natural and synthetic membranes. This work focused on drug delivery and chemical separation processes. The potential importance of such techniques to protein separations in biotechnology has led to collaborative support in the new Biotechnology Process Engineering Center at MIT. Recent results have shown that modulation of the charge density of synthetic hydrogel membranes can be used to control the membrane transport of two proteins important in biotechnology applications, serum albumin and ribonuclease. These findings suggest the feasibility of using active electrical control to separate such proteins from a cell culture broth in a scaled up process.

Several years ago Prof. Raphael Lee and his students discovered that connective tissue fibroblasts were very sensitive to electric fields and the level of sensitivity was strongly frequency dependent. The underlying transductive coupling mechanism responsible for this effect is unknown. However, recently they discovered that membrane vesicle transport pathways were effected by fields of the same frequency and magnitude as used in the previous studies. This is the first evidence for a specific mechanism which could explain the effects that were recently reported by Dr. McLeod and Prof. Lee in Science (June 12, 1987).

Advances continue to be made in the study of tissue remodeling by Lee and his co-workers. They have now completed the construction of an apparatus which allows the measurement of tissue mechanical properties during dynamic states of wound healing, tissue growth, and remodeling. Evidence has been found that fibroblasts possess the capability of degrading tissue devoid of macrophages. These experiments are the first of their type and promise to give more quantitative understanding of the dynamics of tissue growth and remodeling processes.

In another project they have produced substantial evidence that strong electric fields, characteristic of those established in electrical trauma, are likely to alter the structure of cell membranes. Electrically large cells, such as peripheral nerve and muscle cells, are more susceptible to this injury. It is hoped that this discovery may lead to new ways to treat the victims of accidental electrical injury.

In cooperation with Prof. E. Merrill and his students in Chemical Engineering, Mr. Wright has been studying the effects of varying doses of electron beam irradiation on polyethylene oxide (PEO). At present they are planning to increase the dose rates by developing beam scanning techniques. As one of the applications of irradiated PEO in combination with, for example, benzene or chlorobenzene in water they have shown, using high performance liquid chromatographic techniques, that a relatively low radiation dose reduces the number of degradation peaks and peak heights. It is hoped that the PEO gels, which are formed during irradiation, will provide a means of removing the degradation products from water by attachment and subsequent filtration.

Power System Integration and Electronics

In this work on Demand-Side Management, Prof. F.C. Schweppe and Dr. R.D. Tabors continued to evolve the appliance signature technique. This enables monitoring of individual appliance usages within a house by observing voltages and currents at the service box. A general theory has been achieved of identifying in-state, finite state, machines. An in depth survey for both industrial customers and utilities on research needs in the area of load management was conducted. Increasing customer involvement in electric power systems via a spot priced based energy marketplace continues to be stimulated by Schweppe and Tabors. As they become more deeply involved in the ever broadening national discussions on wheeling and deregulation of power systems, a book is almost completed and will be published soon by Kulwer Press.

Relative to Power Systems Planning, studies using MIT developed EGEAS computer system provided solid support for the hypothesis that combined cycle gas turbine systems have an important future. Basic work on techniques for solving power system planning problems involving multiple attributes, multiple decision makers, and massive uncertainty continued. Their approach, which concentrates on throwing out inferior strategy, noncritical uncertainties, and unimportant attributes presently appears to be superior to attempts to find optimum solutions.

JAMES R. MELCHER
The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental research laboratory of the Massachusetts Institute of Technology. Its staff includes faculty members, full-time research scientists, postdoctoral fellows, graduate research assistants, and support personnel. Undergraduate students participate in the research program of the Laboratory through the Undergraduate Research Opportunities Program (UROP). Every year several research scientists from various parts of the world visit the Laboratory to participate in its research program.

The fundamental research goal of the Laboratory is to advance the field of systems, communication and control. In doing this it explicitly recognizes the interdependence of these fields and the fundamental role that computers and computation play in this research. The Laboratory is conducting basic theoretical studies in communication and control and is committed to advancing the state of knowledge of technologically important areas. For example, Flexible Manufacturing Systems is currently an important research area in the Laboratory.

As an interdepartmental laboratory, LIDS reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. The Co-Directors of the Laboratory are Robert G. Gallager, Professor of Electrical Engineering, and Professor Sanjoy K. Mitter, Professor of Electrical Engineering. The Assistant Director is Stanley B. Gershwin, Principal Research Scientist.

The Center for Intelligent Control Systems, an inter-university, interdisciplinary research center operated by a consortium of Brown University, Harvard University and MIT, resides administratively within the Laboratory for Information and Decision Systems.

Thirty-one faculty members, six research staff members and approximately seventy-five graduate students are presently associated with the Laboratory and the Center. Currently, the Laboratory and the Center provide some 50 research assistantships to graduate students. Undergraduate students also participate in research and thesis activities. A number of postdoctoral and visiting appointments are also made.

Financial support for research is provided by the U.S. Army Research Office, Office of Naval Research, Air Force Office of Scientific Research, University Research Initiative Program, National Aeronautics and Space Administration, National Science Foundation, National Institutes of Health, IBM Corporation, Dupont Corporation, General Electric Company, Data General Corporation, and Bell Communications Research, Inc.

CURRENT RESEARCH

The current research activities of the Laboratory cover a wide range of theoretical and applied areas in systems, communications, and control. These areas include:

Data Communication Networks

Research in Communication Science and Systems ranges from basic information theoretical studies of networks and communication channels to the architectural design of network protocols. The major objective of this work is to develop the scientific base needed to design data communication networks that are efficient, robust, and architecturally clean. Both wide area and local area networks and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are routing, flow control, diverse traffic mixes, the communication complexity and delay of distributed algorithm protocols, multiaccess contention resolution, failure recovery and topological design. Professors Dimitri Bertsekas, Robert Gallager, Pierre Humblet, and Robert Kennedy are conducting this research.

Center for Intelligent Control Systems

The Center for Intelligent Control Systems, established October 1, 1986, is an inter-university, interdisciplinary center for research in the foundations of intelligent machines and intelligent control systems administratively within LIDS. The Center is operated by a consortium consisting of Brown University, Harvard University and MIT. Dr. Sanjoy K. Mitter, Professor of Electrical Engineering at MIT, serves as Director of the Center with Professors Roger W. Brockett and Donald W. McClure, from Harvard University and Brown University, respectively, as Associate Directors. The Center will involve approximately 30 faculty, 6 postdoctoral students, and 18 graduate students. The research and educational mission of the Center is directed toward the further development of the conceptual and mathematical aspects of the study of intelligent control systems drawing on relevant work in mathematics, statistics, communications and computer science as well as work in control theory itself.
Fiber Optic Local Communication Networks

The goal of this newly initiated program is to identify and resolve the fundamental issues pertaining to the design of local communication networks that utilize very broad and optical fiber technology to realize an integrated system that can provide all necessary communication services in a campus environment. Theoretical, experimental and design activities will contribute to the work.

Particular emphasis will be placed upon taking full advantage of the unique capabilities of single mode fiber technology. For example, the use of fiber couplers to increase the number of users that can be accommodated without repeaters will be investigated. Another effort will explore the use of tunable optical fibers and heterodyne detection to achieve dynamic frequency concurrency. Professors Robert Kennedy and Pierre Humblet are conducting this research.

Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis and signal processing problems are being studied by Professors Bernard Levy, Sanjoy Mitter, John Tsitsiklis, George Verghese, and Alan Willsky and their students. Theoretical studies are conducted in the areas of estimation algorithms for spatially distributed random processes, nonlinear filtering, relationships among filtering problems in scattering theory, and the analysis of large-scale systems subject to a variety of very rare events. Complementing this theoretical research are more applied projects, including the design of algorithms for detecting and compensating for sensor or actuator failures, and the development of model-based signal processing algorithms. The specific signal processing problems include the diagnosis of arrhythmias in electrocardiograms, the detection of objects or anomalies given tomographic measurements such as those made using X-rays or ultrasound in medical and industrial nondestructive testing applications, the analysis and inversion of spatially-distributed geophysical data, image processing and understanding and computational vision.

Deterministic and Stochastic Nonlinear Dynamical Systems

The theory of nonlinear systems, both deterministic and stochastic, has developed rapidly during the last ten years. There is increasing interest in deterministic nonlinear control and various problems of adaptive control which lead to problems of nonlinear control. In the context of stochastic dynamical systems, problems of the qualitative behaviors of such systems under different time-scales are of great interest. Recent work on nonlinear filtering has shown their relationship to infinite-dimensional, bilinear systems, and there is increasing interest in the understanding of qualitative behavior of nonlinear filters for large and small time-intervals. Various investigations in this area are being conducted by Professors Athans, Mitter, Verghese, Willsky, and their students.

Multivariable and Adaptive Control

Systematic design of multiple-input-multiple-output systems, using a unified time-domain and frequency-domain framework is an extremely active research area in the Laboratory. Various theoretical and applied studies are being carried out by Professor Michael Athans, Sanjoy Mitter, H. Austin Spang III, Gunter Stein and Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of helicopters, submarine control systems, engine control system designs, and issues of integrated flight control.

Theory and Algorithms for Optimization

This project focuses on analytical and computational methods for solving broad classes of optimization problems arising in engineering and operations research, as well as for applications in communication networks, control theory, power systems, computer-aided manufacturing and other areas. Currently, in addition to traditional subjects in nonlinear and dynamic programming, there is an emphasis on solution of large-scale problems involving network flows and differential and difference equation dynamics. The thrust is twofold: first, to find ways to handle the typically huge number of constraints; second, to explore the use of distributed and parallel processing to reduce the computation time needed to solve a problem and to economize on information transfer from remote data collection points to a computation center. This gives rise to fundamental issues involving the synchronization of computation and communication that are as of yet only partially resolved. Professor Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

Command, Control, and Communication Systems

The study of military Command, Communication and Control (C^3) systems defines basic research directions in the areas of distributed communication and decision problems, organizational architectures, and decision aiding for human decision makers in a stressful environment. Professor Michael Athans and Dr. Alexander H. Levis, together with a large group of graduate students, are developing novel theoretical and algorithmic approaches for this rich class of system-theoretic problems.
Recent advances have been made in the following areas: (a) organization structures based on information-theoretic concepts; (b) mathematical models of distributed decision problems with limited communications; and (c) distributed dynamic resource allocation problems.

Manufacturing Systems

Modeling, analysis, and control of manufacturing systems are studied by Dr. Stanley B. Gershwin, Professor Sanjoy K. Mitter, Dr. Xi-Cheng Lou and their students. The effects of machine failures on routing and scheduling policies are investigated to reduce in-process inventories and the time spent by material in the factory. The architecture of an on-line computer system that will optimally control the flow of material is being considered. The concept of a transfer, or production, line has been extended to that of an assembly/disassembly network for the purpose of studying the interplay between reliability, speed, buffer size, production rate, and average in-process inventory levels. A special area of our activities is in the Computer-Aided Fabrication of VLSI semiconductor chips.

Information Transfer and Retrieval

Research on information transfer and retrieval focuses on investigating issues concerning the way computer-based information systems can be engaged more easily and effectively by potential human users. These investigations involve the application of theoretical, analytical, and experimental techniques in areas such as information and computer science and technology, computational linguistics, and psychological human-factor studies.

Several current projects center on analytical and experimental investigations of expert computerized intermediary systems to assist end-users in accessing and operating heterogenous bibliographic databases and retrieval systems. Expert assistance requires mixed-initiative (computer and human directed) actions to develop for any problem a conceptual formalization followed by an interactive process of search strategy formulation, execution, evaluation, and modification. Staff members who have supervised these efforts include Mr. Richard S. Marcus and Professor J. Francis Reintjes.

System Reliability and Risk Management

Research on risk assessment and management is carried out in many MIT departments and laboratories. In LIDS there is interest in describing the reliability of complex systems in terms of what is known about the reliability of their components. Professor Alvin Drake has supervised research on the development of models and algorithms for studying the manner in which uncertainties about component reliabilities are reflected in uncertainty about system reliability. The primary area of application has been to low probability, high consequence risks in nuclear reactor safety. Professor Drake is also concerned with probability assessment, particularly the quantification of expert judgement. A current project is a detailed probabilistic analysis of the sequence of tests used to screen donated blood for the presence of AIDS-associated antibodies.

Highlights

Among the distinguished speakers in the Laboratory's Colloquia Series were Professor W.M. Wonham of the University of Toronto who gave the lecture "On Control of Discrete Event Systems," and Professor Herbert A. Hauptman, winner of the 1985 Nobel Prize in Chemistry, who spoke on "The Phase Problem of X-Ray Crystallography."

Professor John Tsitsiklis was promoted from Assistant to Associate Professor. Professor Tsitsiklis and Professor Michael Athans received the Outstanding Paper Award by the IEEE Control Systems Society given at the December 1986 Conference on Decision and Control for their paper "On the Complexity of Decentralized Decision Making and Detection Problems."

Professor Robert Gallager and Professor Dimitri Bertsekas published their book Data Networks and Professor Bertsekas's book Dynamic Programming also appeared.

Professor Sanjoy Mitter was invited to lecture in the "Evolution Equation Year" at the Scuola Normale in Pisa, Italy. He was also invited to lecture at the First International Conference on Advances in Communication and Control Systems held in honor of Professor A.V. Balakrishnan.

Professor Alan Willsky was elected Vice President for Technical Affairs of the IEEE Control Systems Society for 1987 and 1988. He was also invited to be one of the lead speakers at the NSF Workshop on Future Directions in Control in October 1986.

SANJOY K. MITTER
The Laboratory for Manufacturing and Productivity (LMP) is an Engineering School Laboratory composed of faculty, staff and students from several (engineering) departments. The LMP is concerned with the study and improvement of manufacturing productivity based on fundamental engineering research and the education of engineers who can provide leadership in this rapidly changing field. Our research ranges from the detailed process physics level to the general system level and covers primarily (but is not limited to) mechanical production. While most of the research is conducted along the lines of conventional engineering sciences, an increasing fraction is forging new methods, philosophies and concepts to deal with the complex, multidisciplinary nature of manufacturing. In doing so, we seek unique means for characterizing and solving problems in manufacturing.

The LMP is also the base for substantial curriculum and textbook development in the manufacturing field. This is perhaps one of our most important areas of activity, principally because of the tremendous need for professionals aware of advanced manufacturing technology and because of the dearth of modern texts combined with a sustained student and industry demand for advanced subjects in this area.

The LMP is home to more than 70 graduate students, who are supervised by 15 faculty from five departments (Mechanical Engineering, Materials Science and Engineering, Chemical Engineering, Ocean Engineering and Civil Engineering), three research staff and a technical support staff. UROP students play a major role in our research, and numbered more than 40 in the past year. The LMP reports to the Dean of Engineering, Professor Gerald Wilson. David Hardt, Associate Professor of Mechanical Engineering, serves as Director, and Professor Steven Dubowsky, Professor of Mechanical Engineering, serves as Associate Director.

The Lab derives more than 60 percent of its research support from more than 25 separate sponsors from industry. Many of these participate in our Industry Consortia, which include The Industry Polymer Processing Program, The Tribology Research Program, The Intelligent Manufacturing Systems Program and The Knowledge Systems Program. The remaining support is provided by various government agencies including the Department of Energy, the Office of Naval Research, the National Science Foundation, the National Bureau of Standards, and the Army Materials Laboratory. In addition, the LMP Industry Collegium, which now has over 35 members, serves as an information and liaison organization for companies directly interested in manufacturing research.

CURRENT RESEARCH

The research of the LMP can be broadly classified into two major categories: Manufacturing Processes and Manufacturing Systems. The manufacturing process research is conducted almost entirely within three areas: Polymer and Composite Processing, Tribology, and Flexible Automation and Robotics. In addition, there is an emerging area of research dealing with advanced processing methods such as laser based systems. While all of the research in these programs is closely tied to or directly concerned with a particular process or class of processes, there exists a spectrum of objectives within this work. What ties this work together is a firm grounding in the fundamental understanding of the relevant physics in each process. This understanding is gained for several purposes: process improvement, process innovation and process control.

As process automation and control have become more mature, the collection of autonomous processes into systems has emerged as an important research topic. It is also apparent that a "systems" approach is useful even with conventional facilities. The method of integration of processes, the planning and schedul-
ing of the systems, and the interface with management functions are the pri-
mary thrusts of the new Intelligent Manufacturing Systems Program within the
LMP. This program, along with the recently formed Knowledge Systems Program,
is seeking new methods for developing rational decision making methods for
both specific systems of processes and for strategic issues of product and
process design.

NEW APPOINTMENTS

Our newest faculty member is Dr. Emanuel Sachs, whose appointed
Assistant Professor of Mechanical Engineering on July 1, 1986. Ely received
his Ph.D. from MIT in 1982, and has been involved in the development and com-
mercialization of a continuous silicon ribbon crystal growth process. His
work within the IMP is centered on methods for optimum process design and op-
eration and on specific process innovations in the semiconductor material
area. He is also playing a major role in our manufacturing curriculum revi-
sion effort.

Prof. Harry West, who was also appointed Assistant Professor in 1986, is con-
tinuing his work in the IMP in braced manipulation. This novel concept allows
high force, precision manipulation with conventional robots simply by adding a
carefully designed passive linkage system to the endpoint.

Prof. Don Clausing, Gordon Adjunct Professor of Electrical Engineering, has
joined the IMP in this last year, and has been conducting research in the
"Process of Engineering". He brings considerable experience, most recently
with Xerox, in Mechanical and Materials Engineering and has had a major in-
fluence on our thinking of how the product-process development cycle should be
executed.

The IMP Collegium has been given a major boost with the appointment of Ms.
Sally Burns as Assistant to the Director. Sally had over 10 years experience
running a similar program in Computer Science at Stanford, and more recently
was the Operations Manager for a start-up computer firm in Massachusetts.

NEW INITIATIVES

Several new research projects have begun in the past year, including two in
the crucial area of design/manufacturing integration. Under the direction of
Prof. Kim, an industry sponsored program has lead to the development of an In-
telligent Design Advisor that aids in design choices based upon knowledge sys-
tem concepts and a comprehensive view of the product, materials and process
options. In a more pragmatic program, (sponsored by ONR and executed jointly
by the IMP, the Material Processing Center and Sea Grant) the integration of
design and manufacturing for ship hull construction is being approached
through combined CAD and process modelling efforts.

Prof. Chryssolouris has expanded his laser machining effort with the installa-
tion of a twin 800 W laser system. This equipment permits extensive experi-
mentation with multiple beam strategy for high material removal rate in metals
and ceramics. Prof. Gutowski's work in advanced composite materials has been
expanded to include studies of the "automation economics" of various process-
ing methods, and has lead to rather controversial findings. Prof. Ming-Kai
Tse has launched a new program in Tribo-Acoustics, the process of using sur-
face interactions to diagnose process status. This NSF sponsored program will
combine our efforts in Non-Destructive Evaluation with our long-standing funda-
mental Tribology work

In a related matter Prof. Tse developed and taught (with support from Profs.
Rabinowicz and Clausing) a graduate subject in the area of NDE and Quality
Evaluation. This course fills a void in our manufacturing curriculum and was
so well received that Prof. Tse was awarded the GSC outstanding teaching
award.

With the addition of Ms. Burns to our Staff, the IMP Collegium has expanded to
include over 35 companies, and the Collegium will introduce several new ser-
vice for its members, the most important of which will be to facilitate the
recruitment of students educated in the emerging areas of advanced manufactur-
ing.
During the spring of 1987, a subcommittee of the LMP developed a comprehensive curriculum plan for mechanical engineering that has identified key core areas of instruction, and has added to the potential scope of manufacturing subject offerings by incorporating both system and design issues. Major parts of this plan are now being implemented through new subject development and revisions of existing offerings.

DAVID E. HARDT
The Materials Processing Center (MPC), formed within the Massachusetts Institute of Technology's (MIT) School of Engineering in 1980, catalyzes the generation and transfer of scientific information necessary to promote progress in the materials processing field. Founded with a NASA grant to establish a research base in materials processing, the MPC has rapidly expanded to a current annual research budget of $7.5 million. NASA still provides about 11 percent of the MPC's total budget, with 39 percent provided directly by industry, and another 50 percent from other governmental agencies.

INTERDISCIPLINARY, FUNDAMENTAL RESEARCH

The MPC's basic philosophy is that it is through processing that the internal structure on both the macroscopic and the microscopic level can be controlled, thus influencing a material's properties and performance. Processing control must be based on scientific fundamentals, rather than the more traditional empiricism.

An MPC goal is to increase the number of materials processing students and professionals, thereby expanding the talent base available for industry. This expansion is crucial, since requests from industry for materials research and development engineers and scientists are about three times the number of these professionals graduating.

MPC research covers a broad range of materials and activities, with a number of common themes. The foremost theme running through all MPC research is the control of structure, properties, and performance at costs that are acceptable both socially and economically. In addition, projects have both practical and fundamental significance, with many related to low-gravity, space processing. Researchers in both ground-based and low-gravity environment-based studies are increasing their use of mathematical modeling techniques as a research tool. Another theme common to MPC projects is the interdisciplinary nature of the research. Projects typically involve a number of faculty, staff, and students from several departments, including Chemical Engineering, Civil Engineering, Physics, Nuclear Engineering, Materials Science and Engineering (DMSE), Mechanical Engineering, Electrical Engineering and Computer Science (DEECS), and Chemistry.

Three new programs, begun in the past year, emphasize the interdisciplinary focus of the MPC. An alliance with the Crystal Physics and Optical Electronics Laboratory (CPOEL) brings the MPC into a new research area – the science and technology of electrical, optical, and magnetic materials and their application in devices like diode-pumped lasers and photoelectrodes. Another alliance, this time with the Microsystems Technology Laboratory, engages the MPC in the field of electronic device packaging, which is critical to electronic device performance. This new effort uses microfabrication technologies to create test structures with thin polyimide films for a wide variety of physical and chemical measurements. A third program draws upon the collective expertise of researchers in the Ceramics Processing Research Laboratory (CPRL), DMSE, DEECS, CPOEL, and MPC to determine the basic processing science behind the new oxide superconductors.

COLLABORATION WITH INDUSTRY

The MPC believes that due to the rapid rate of scientific and technological innovation, new mechanisms must be developed to facilitate the transfer of scientific information and technology to industry in ways that go beyond the traditional modes of research publication and student graduation. Collaboration with industry is critically important to the university, providing academic programs with the long-term direction necessary to maintain a high degree of relevance to rapidly evolving industrial needs.

Since its inception, the MPC has encouraged a close relationship with industry through its Industrial Advisory Board, Industry Collegium, and multi-client research consortia. The Board, whose 26 members all come from U.S. industry and government, annually reviews ongoing MPC research programs and policies. The Collegium, now with 60 corporate member companies worldwide, encourages close contact between industrial representatives and MPC personnel through seminars, visits, and tours of the research facilities. Person-to-person contact between visiting scientists from these companies and MPC faculty, staff, and students encourages the flow of creative ideas in both directions, while providing excellent opportunities for bilateral information and technology exchange.

The MPC adopted the consortia, or multi-client sponsored research concept, in 1980 to promote collaborative, generic materials processing research. A new consortium, which is in the planning stage, the Materials Synthesis Laboratory (MSL), will combine the talents of experts in electronic
structure theory, inorganic synthetic chemistry, crystal chemistry, and materials science to understand in greater detail bonding and crystal chemistry, eventually hoping to predict and synthesize entirely new families of solids that exhibit novel properties. The MSL will join five previously organized consortia: the Ceramics Processing Research Laboratory, the Laboratory for the Processing and Evaluation of Ceramic and Metal Composites, the Materials Systems Laboratory, the Mathematical Modeling Laboratory, and the Resistance Welding of Automotive Steels. Through groups such as these, the MPC strengthens the link between basis research at the university and innovation in industry.

EDUCATION: BEYOND THE TRADITIONAL

In addition to its research role, the MPC, through the Collegium, sponsors graduate student fellowships and undergraduate summer scholarships. The fellowship program, established in 1982, endeavors to attract the very best entering graduate students to materials processing. For the 86/87 academic year, the MPC offered six fellowships to students in the Departments of Materials Science and Engineering, Electrical Engineering and Computer Science, Mechanical Engineering, and Chemical Engineering. Similarly, the summer scholarship program, also begun in 1982, seeks to alert undergraduate students to the opportunities available in a career in materials processing at MIT. For the summer of 1987, the MPC awarded four summer scholarships to sophomores and juniors enrolled in chemical engineering, electrical engineering, mechanical engineering, and materials science in universities throughout the United States. During the summer, these undergraduates participate in ongoing materials processing research programs before returning to their respective schools in the fall to complete their undergraduate programs.

The MPC's commitment to education goes beyond the traditional academic role. The MPC and Professor H. Kent Bowen, along with the School of Engineering and The Sloan School, are exploring ways to nurture and improve the next generation of manufacturing leaders in the Leaders for Manufacturing Program. Current events have revealed underlying and growing weaknesses in the traditional organization of U.S. manufacturing enterprises. Revitalizing American manufacturing industries depends directly on a national ability to generate managers who understand technology, know how to assess its potential, and know how to implement it. The Leaders for Manufacturing Program will rely on wholly new approaches to integrate technology and management in educational and research programs. The program will collaborate with industry to accelerate the development of interdisciplinary research responsive to industry needs. Key components of the program will create industry-MIT research teams, undertake major research programs at industrial sites, and develop manufacturing "practice schools" at industrial facilities.

TIMELY INFORMATION EXCHANGE

Each year, the MPC hosts several symposia, each covering an area of ongoing research in materials processing at MIT, for the benefit of the Collegium member companies. The major rewards of the seminars, which have been well attended by industrial, university, and government personnel, are the timely dissemination of research results and the ensuing exchanges between speakers, MPC staff, and attending industrial representatives. These symposia also provide an opportunity for graduate students to become acquainted with practicing engineers and scientists from industry. Symposia held last year dealt with "The Science and Control of Welding and Joining Processes," "Processing, Microstructure, and Properties of Metal and Ceramic Matrix Composites," "Mathematical Modeling of Materials Processing," and "Materials Research for Electronic Device Packaging."

The Materials Processing Center, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past seven years, the MPC has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. Through such collaboration and cooperation, we expect to exercise our leadership role in the evolution of new materials, and, ultimately, to transfer materials processing know-how into the worldwide marketplace.

R. M. LATANISION
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

Affirmative action continues to be a major concern of the School of Humanities and Social Science, whose goal is to have a strong presence of women and minority faculty members in each of the departments, programs, or sections within the School. While the School has been reasonably successful in achieving this goal with respect to women, it has been considerably less so with respect to minorities. Thus each unit within the School is developing a list of the pool of underrepresented minorities within its disciplines, and is actively recruiting minority faculty. This past year, offers to three minority faculty members were made (two tenured, one untenured) and one was accepted at the assistant professor level. Even with this addition, there will only be five minority faculty members within the School of Humanities and Social Science (three full professors, and two assistant professors, one of whom is a woman).

The School's record with regard to women is considerably brighter, where 24.5 percent of the faculty are women. Not surprisingly, women are represented significantly more in the untenured faculty ranks, where 41.5 percent of the faculty are women, than in the tenured faculty ranks, where 17.3 percent of the faculty are women. Nevertheless, both figures compare favorably with the rest of the Institute. Moreover, two of the four individuals who received tenure in the School this year were women. Thus the proportion of women in the School's senior faculty ranks should continue to grow.

This year saw the culmination of a number of curricular initiatives related to the role of the Humanities, Arts, and Social Sciences (HASS) within the Institute's undergraduate curriculum. Most notable of these was the restructuring of the Humanities Distribution requirement and the establishment of a new HASS minor.

The new HASS Distribution requirement was developed to ensure that students receive a broad and cohesive exposure to the humanities, arts, and social sciences. Under it, students must take three subjects from one of the following five categories: Literary and Textual Studies; Language, Thought and Value; the Arts; Societies and Cultures; Historical Studies. In addition, students must take at least one subject from categories 1 or 2 (humanities) and 4 or 5 (social sciences). Thus the new requirement, which will be phased in over three years beginning AY1988-89, will impose considerably more structure on the distribution component of the HASS requirements than the current distribution component, under which students must take three subjects out of a list of 22 categories. In addition, it is expected that there will be substantially fewer subjects offered under the new HASS-Distribution system than under the old Humanities-Distribution system.

In addition, the faculty approved the establishment of a new HASS-minor in the fields in which students may currently major. This program is aimed at developing dual literacy by encouraging students to take a structured program in one of the disciplines within the humanities, arts, and social sciences to complement their field of major study in a scientific or technical area. Under it, students must take six subjects in an approved minor field, and they will receive designation of that particular minor on their degree. In this way, it is hoped that students will be encouraged to delve more deeply in the HASS disciplines than they do under the current concentration requirements.

Other curricular initiatives included the development of a number of new, experimental subjects in the human and social context of science and technology. During the AY1987-88, four or five subjects will be offered by teams of faculty from the Schools of Science, Engineering, and Humanities and Social Science, exploring such diverse topics as technology and politics; negotiation and engineering systems; and industrial competitiveness and social structure. It is hoped that the range and number of these offerings will expand in the future so that they will become an integral part of the undergraduate curriculum.

A number of other activities are also underway to encourage intellectual interactions between the humanistic and scientific/technical cultures. One of these is embodied in the new Robert M. Metcalfe Professorship in Engineering and the Liberal Arts, which will be jointly shared by a faculty member in the School of Engineering and in the School of Humanities and Social Science to develop initiatives for new intellectual linkage between these two Schools. The first holders of this chair will be Professor Joel Clark of the Department of Materials Science and Engineering and Associate Professor Peter Perdue of the History faculty. In addition, previous initiatives related to the Integrated Studies Program, the Burchard Scholars, and the faculty-to-faculty mini subjects continue to be popular. This year, the Integrated Studies Program moved to Building 20, where it would be in close proximity to the other freshman initiatives. It continued to attract a significant number of freshmen interested in making intellectual connections between the Institute's science and HASS requirements.
In view of the strong response to the Burchard Scholars Program, which was initiated last year, the Program was expanded from 13 to 20 students, each of whom have each exhibited unusual strengths in scientific/technical and humanistic areas. This summer two new faculty-to-faculty mini subjects were introduced: one offered by the Literature faculty dealt with the development of the epic and Joyce's Ulysses; a second offered by the Biology faculty dealt with microbiology and its implications for society. Each was taken by over 30 faculty members from all of the Schools within the Institute. In addition, the mini subject on world politics was offered again in view of last year's strong demand. The participants felt that these subjects offer a unique opportunity for faculty from different disciplines and different schools to work together on a common intellectual enterprise. It is likely that the range of these subjects will be expanded in the future.

I am happy to report that student interest in the School of Humanities and Social Science continued to grow, with the number of majors increasing from 111 to 135. Most of these gains were made in the disciplines within the Humanities, indicating that MIT students see a growing need to be conversant with the humanistic as well as the technical worlds.

It is important to note, however, that the programs and sections that comprise the Humanities Department are still in an essentially service role, with relatively few students taking subjects in these areas beyond those necessary to satisfy the Institute's HASS requirements. The faculty are hopeful, however, that the recent emphasis on the importance of humanities in a technical education and the recent changes in the admissions procedures may change this so that the Institute will attract an increasing number of students with a fundamental interest in the humanities. Nevertheless, in the absence of graduate programs, the Humanities faculty will continue to be relegated to a predominantly service role, with its attendant problems.

A number of specialized graduate programs related to the disciplines in the Humanities would clearly be desirable. In this connection, I am pleased to note that the faculty within Anthropology, History, and the Program in Science, Technology, and Society are actively developing a new graduate program in the History and Social Study of Science and Technology. In addition, preliminary discussions concerning a graduate program in American Studies are underway.

A major administrative change will occur at the beginning of FY1988, when the Music Section will expand to incorporate the theater arts as represented by Dramashop, the Shakespeare Ensemble, and the Dance Workshop. This will bring all of the performing arts activities with a strong academic component together for the first time and should lead to a stronger performing arts program within the Institute. In addition, the music faculty is exploring the development of linkages with the music and cognition group within the Media Lab, which could lead to the creation of a center that would focus on the theory, composition, and performance of electronic and other contemporary music and serve as a focal point of these activities within the Institute.

Over the course of the past year, the School of Humanities and Social Science has intensified its efforts to seek support from alumni, corporations, and foundations for programs within the School. Through the efforts of faculty, staff, and senior officers, major gifts have been received for curriculum development, fellowships, and an endowed lectureship as well as a range of programmatic (departmental) activities.

The faculty within the School of Humanities and Social Science received a number of honors and awards this past year. Most notable was the award of the Pulitzer Prize in Music to Professor John H. Harbison of the Music faculty for his piece, "The Flight into Egypt." In addition, Professor Harbison was elected to the National Academy of Arts and Sciences. Other notable honors include the nomination and/or election of the following School faculty as presidents of their respective professional associations: Professor Thomas S. Kuhn, Laurance S. Rockefeller Professor of Philosophy as President elect of the Philosophy of Science Association; Professor Lucian W. Pye as President of the American Political Science Association; and Professor Merritt Roe Smith as President of the Society for History and Technology. Professor Pauline R. Maier received an honorary degree of Doctor of Laws from Regis College.

I am sorry to report the death of Professor Krystyna Pomorska within the Foreign Languages and Literature faculty. A distinguished scholar of Russian Language and Literature, she will be greatly missed.

On a happier note, I am pleased to report that Associate Professor Philip S. Khoury of the History faculty will become Associate Dean of the School of Humanities and Social Science, effective July 1, 1987. In this capacity he will work to develop and implement the numerous curricular initiatives that are currently underway.

ANN F. FRIEDLAENDER
<table>
<thead>
<tr>
<th>Field</th>
<th>Elective Subjects</th>
<th>Distribution Subjects</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subjects</td>
<td>Students</td>
<td>Subjects</td>
</tr>
<tr>
<td>Anthropology/Archaeology</td>
<td>9</td>
<td>106</td>
<td>7</td>
</tr>
<tr>
<td>Economics</td>
<td>19(^2)</td>
<td>1148</td>
<td>3</td>
</tr>
<tr>
<td>Foreign Languages &amp; Literatures</td>
<td>44(^6)</td>
<td>900</td>
<td>28(^3)</td>
</tr>
<tr>
<td>History</td>
<td>22</td>
<td>318</td>
<td>19</td>
</tr>
<tr>
<td>History of Art &amp; Architecture</td>
<td>2</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>Interdisciplinary</td>
<td>2</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>Linguistics</td>
<td>1(^1)</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>Literature</td>
<td>23</td>
<td>337</td>
<td>23(^3)</td>
</tr>
<tr>
<td>Music</td>
<td>22(^9)</td>
<td>509</td>
<td>8(^2)</td>
</tr>
<tr>
<td>Philosophy</td>
<td>16</td>
<td>316</td>
<td>9</td>
</tr>
<tr>
<td>Political Science</td>
<td>28</td>
<td>287</td>
<td>11</td>
</tr>
<tr>
<td>Psychology</td>
<td>9</td>
<td>719</td>
<td>0</td>
</tr>
<tr>
<td>Science, Technology &amp; Society</td>
<td>12</td>
<td>65</td>
<td>9</td>
</tr>
<tr>
<td>Theatre and Dance: Performance</td>
<td>6(^7)</td>
<td>72</td>
<td>0</td>
</tr>
<tr>
<td>Traditions &amp; Texts</td>
<td>0</td>
<td>0</td>
<td>7(^8)</td>
</tr>
<tr>
<td>Urban Studies</td>
<td>3</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Visual Arts &amp; Design</td>
<td>16</td>
<td>415</td>
<td>1</td>
</tr>
<tr>
<td>Writing</td>
<td>25(^3)</td>
<td>413</td>
<td>8(^1)</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>259(^3)</td>
<td>5702</td>
<td>132(^1)</td>
</tr>
</tbody>
</table>

**NOTE:** Figures were obtained from the grade/subject distribution report which shows the final tally for each class. The numbers shown are for undergraduate subjects which normally satisfy the HASS Requirement; they do not include subjects allowed towards the Requirement only upon petition. Superscript is number of autonomous class sections if more than one; this does not apply to subjects which meet in a single lecture once or twice a week and divide into discussion sections for a single meeting.
<table>
<thead>
<tr>
<th>Fields of Concentration</th>
<th>Class of 1990</th>
<th>Class of 1989</th>
<th>Class of 1988</th>
<th>Class of 1987</th>
<th>Totals in Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Studies</td>
<td>(0) 0</td>
<td>(1) 0</td>
<td>(5) 2</td>
<td>(9) 9</td>
<td>(15) 11</td>
</tr>
<tr>
<td>Ancient and Medieval Studies</td>
<td>(0) 0</td>
<td>(1) 0</td>
<td>(5) 0</td>
<td>(3) 3</td>
<td>(9) 3</td>
</tr>
<tr>
<td>Anthropology/Archaeology</td>
<td>(1) 0</td>
<td>(2) 0</td>
<td>(5) 0</td>
<td>(15) 14</td>
<td>(23) 14</td>
</tr>
<tr>
<td>Economics</td>
<td>(0) 0</td>
<td>(41) 5</td>
<td>(116) 41</td>
<td>(243) 225</td>
<td>(400) 271</td>
</tr>
<tr>
<td>Film and Media Studies</td>
<td>(0) 0</td>
<td>(4) 0</td>
<td>(4) 1</td>
<td>(7) 5</td>
<td>(15) 6</td>
</tr>
<tr>
<td>Foreign Languages &amp; Literatures**</td>
<td>(3) 0</td>
<td>(50) 12</td>
<td>(117) 60</td>
<td>(228) 200</td>
<td>(398) 272</td>
</tr>
<tr>
<td>History</td>
<td>(1) 0</td>
<td>(17) 0</td>
<td>(41) 16</td>
<td>(72) 63</td>
<td>(131) 79</td>
</tr>
<tr>
<td>History of Art and Architecture</td>
<td>(0) 0</td>
<td>(2) 0</td>
<td>(4) 0</td>
<td>(8) 8</td>
<td>(14) 8</td>
</tr>
<tr>
<td>Labor in Industrial Society</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(0) 0</td>
</tr>
<tr>
<td>Latin American Studies</td>
<td>(0) 0</td>
<td>(1) 0</td>
<td>(1) 0</td>
<td>(2) 1</td>
<td>(4) 1</td>
</tr>
<tr>
<td>Linguistics</td>
<td>(0) 0</td>
<td>(6) 1</td>
<td>(7) 3</td>
<td>(1) 1</td>
<td>(14) 5</td>
</tr>
<tr>
<td>Literature</td>
<td>(0) 0</td>
<td>(11) 0</td>
<td>(49) 9</td>
<td>(105) 90</td>
<td>(165) 99</td>
</tr>
<tr>
<td>Music</td>
<td>(3) 0</td>
<td>(34) 0</td>
<td>(80) 12</td>
<td>(77) 63</td>
<td>(194) 75</td>
</tr>
<tr>
<td>Philosophy</td>
<td>(0) 0</td>
<td>(6) 2</td>
<td>(23) 7</td>
<td>(57) 48</td>
<td>(86) 57</td>
</tr>
<tr>
<td>Political Science</td>
<td>(0) 0</td>
<td>(17) 0</td>
<td>(25) 4</td>
<td>(60) 54</td>
<td>(102) 58</td>
</tr>
<tr>
<td>Psychology</td>
<td>(0) 0</td>
<td>(25) 3</td>
<td>(66) 17</td>
<td>(99) 89</td>
<td>(190) 109</td>
</tr>
<tr>
<td>Russian Studies</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(1) 0</td>
<td>(1) 0</td>
</tr>
<tr>
<td>Science, Technology, and Society</td>
<td>(0) 0</td>
<td>(4) 0</td>
<td>(3) 1</td>
<td>(15) 15</td>
<td>(22) 16</td>
</tr>
<tr>
<td>Theatre Arts</td>
<td>(1) 0</td>
<td>(1) 1</td>
<td>(4) 1</td>
<td>(13) 9</td>
<td>(19) 11</td>
</tr>
<tr>
<td>Traditions and Texts</td>
<td>(0) 0</td>
<td>(0) 0</td>
<td>(4) 1</td>
<td>(6) 5</td>
<td>(10) 6</td>
</tr>
<tr>
<td>Urban Studies</td>
<td>(0) 0</td>
<td>(1) 0</td>
<td>(1) 0</td>
<td>(9) 8</td>
<td>(11) 8</td>
</tr>
<tr>
<td>Visual Arts and Design</td>
<td>(0) 0</td>
<td>(2) 0</td>
<td>(15) 3</td>
<td>(38) 28</td>
<td>(55) 31</td>
</tr>
<tr>
<td>Women’s Studies</td>
<td>(0) 0</td>
<td>(3) 0</td>
<td>(4) 1</td>
<td>(11) 9</td>
<td>(18) 10</td>
</tr>
<tr>
<td>Writing</td>
<td>(2) 0</td>
<td>(15) 0</td>
<td>(28) 1</td>
<td>(61) 48</td>
<td>(106) 49</td>
</tr>
<tr>
<td>Special Concentrations</td>
<td>(0) 0</td>
<td>(10) 5</td>
<td>(18) 8</td>
<td>(36) 34</td>
<td>(64) 47</td>
</tr>
<tr>
<td>TOTALS</td>
<td>(11) 0</td>
<td>(254) 29</td>
<td>(625) 188</td>
<td>(1176) 1029</td>
<td>(2066) 1246</td>
</tr>
</tbody>
</table>

* The parenthetical figure is the number of proposed concentrations in the given class and field; the figure to its right is the number of these concentrations that have been completed.

** Figures for subfields of Foreign Languages and Literatures:

- French: (2) 0 (17) 1 (43) 18 (76) 67 (138) 86
- German: (0) 0 (10) 4 (25) 13 (55) 49 (90) 66
- Russian: (0) 0 (3) 3 (14) 13 (17) 15 (36) 31
- Spanish: (0) 0 (8) 2 (18) 11 (50) 42 (76) 55
- World Literature in Translation: (1) 0 (1) 0 (5) 0 (8) 7 (15) 7
- Other Languages: (0) 0 (9) 2 (12) 5 (22) 20 (43) 27
## TABLE III

**Undergraduate Majors in the School of Humanities and Social Science***

<table>
<thead>
<tr>
<th>Year</th>
<th>Economics</th>
<th>Humanities**</th>
<th>Philosophy</th>
<th>Political Science</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-75</td>
<td>63</td>
<td>48</td>
<td>1</td>
<td>14</td>
<td>126</td>
</tr>
<tr>
<td>1975-76</td>
<td>67</td>
<td>41</td>
<td>3</td>
<td>24</td>
<td>135</td>
</tr>
<tr>
<td>1976-77</td>
<td>67</td>
<td>31</td>
<td>7</td>
<td>25</td>
<td>130</td>
</tr>
<tr>
<td>1977-78</td>
<td>52</td>
<td>34</td>
<td>7</td>
<td>21</td>
<td>114</td>
</tr>
<tr>
<td>1978-79</td>
<td>48</td>
<td>38</td>
<td>5</td>
<td>30</td>
<td>121</td>
</tr>
<tr>
<td>1979-80</td>
<td>44</td>
<td>37</td>
<td>9</td>
<td>36</td>
<td>126</td>
</tr>
<tr>
<td>1980-81</td>
<td>50</td>
<td>40</td>
<td>11</td>
<td>30</td>
<td>131</td>
</tr>
<tr>
<td>1981-82</td>
<td>51</td>
<td>49</td>
<td>9</td>
<td>32</td>
<td>141</td>
</tr>
<tr>
<td>1982-83</td>
<td>48</td>
<td>37</td>
<td>7</td>
<td>28</td>
<td>120</td>
</tr>
<tr>
<td>1983-84</td>
<td>48</td>
<td>24</td>
<td>3</td>
<td>22</td>
<td>97</td>
</tr>
<tr>
<td>1984-85</td>
<td>52</td>
<td>30</td>
<td>2</td>
<td>15</td>
<td>99</td>
</tr>
<tr>
<td>1985-86</td>
<td>51</td>
<td>52</td>
<td>5</td>
<td>26</td>
<td>134</td>
</tr>
<tr>
<td>1986-87</td>
<td>49</td>
<td>57</td>
<td>7</td>
<td>21</td>
<td>134</td>
</tr>
</tbody>
</table>

* As registered in the second term of academic year 1974-75 to 1986-87. Data taken from the Registrar's fifth-week report.

** These figures do not include double majors who registered first in a course other than Humanities.

## TABLE IV

**Graduate Students in the School of Humanities and Social Science***

<table>
<thead>
<tr>
<th>Year</th>
<th>Economics</th>
<th>Linguistics &amp; Philosophy</th>
<th>Political Science</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-75</td>
<td>114</td>
<td>53</td>
<td>95</td>
<td>262</td>
</tr>
<tr>
<td>1975-76</td>
<td>120</td>
<td>49</td>
<td>89</td>
<td>258</td>
</tr>
<tr>
<td>1976-77</td>
<td>114</td>
<td>46</td>
<td>91</td>
<td>251</td>
</tr>
<tr>
<td>1977-78</td>
<td>123</td>
<td>45</td>
<td>102</td>
<td>270</td>
</tr>
<tr>
<td>1978-79</td>
<td>121</td>
<td>48</td>
<td>96</td>
<td>265</td>
</tr>
<tr>
<td>1979-80</td>
<td>138</td>
<td>63</td>
<td>143</td>
<td>344</td>
</tr>
<tr>
<td>1980-81</td>
<td>126</td>
<td>66</td>
<td>121</td>
<td>313</td>
</tr>
<tr>
<td>1981-82</td>
<td>111</td>
<td>55</td>
<td>142</td>
<td>308</td>
</tr>
<tr>
<td>1982-83</td>
<td>136</td>
<td>51</td>
<td>163</td>
<td>350</td>
</tr>
<tr>
<td>1983-84</td>
<td>113</td>
<td>52</td>
<td>99</td>
<td>264</td>
</tr>
<tr>
<td>1984-85</td>
<td>108</td>
<td>53</td>
<td>121</td>
<td>282</td>
</tr>
<tr>
<td>1985-86</td>
<td>130</td>
<td>59</td>
<td>171</td>
<td>360</td>
</tr>
<tr>
<td>1986-87</td>
<td>105</td>
<td>55</td>
<td>115</td>
<td>275</td>
</tr>
</tbody>
</table>

* As registered in the second term of academic year 1974-75 to 1986-87 (including special graduate students). Data taken from the Registrar's fifth-week report.
At the start of the academic year the Humanities Undergraduate Office was renamed the Humanities, Arts, and Social Sciences Office in order to reflect more accurately the Institute-wide scope of its responsibilities. The Office continued to have two principal components: 1) the Humanities, Arts, and Social Sciences (HASS) Information and Services Center and 2) the Course XXI Undergraduate Office. The increase in volume of student contact for both parts of the office, noted in the past two annual reports, continued in 1986-87. Travis Merritt continued as Director, Ruth Spear as Coordinator. They were joined by Susan Mannett as Course XXI Administrative Assistant. Student assistant was Alexander Oleinik.

HUMANITIES, ARTS, AND SOCIAL SCIENCES INFORMATION AND SERVICES CENTER

The HASS Center's functions remained substantially the same, though with a further increase in volume of business that may be attributed to 1) the Center's extended visibility to the undergraduate student body, 2) a generally heightened awareness of HASS issues which has accompanied MIT's multilateral efforts to improve the program and the requirement, and 3) a somewhat higher degree of "liberal studies" orientation among students admitted in recent classes. Along the same lines, there has been a noticeable shift in the nature of student inquiries from brief, factual questions to requests for in-depth planning sessions for entire HASS programs.

HASS Enrollment Statistics by Field and Subject -- Recent Trends

Year-by-year enrollment figures covering the past three academic years reveals a number of developments possibly with interpretation: 1) a decline in overall enrollments in Foreign Languages and Literatures from 1896 to 1528, with a parallel reduction in number of class sections from 121 to 106; 2) a decline of similar proportions in Economics, with enrollments dropping from 1409 to 1197 and class sections from 52 to 45; 3) growth in History, 645 to 957 enrollments; 4) stability in Literature, at just over 1200; 5) significant enrollment reduction in both of the fields offered by Course IV, History of Art and Visual Studies; 6) a drop from 838 to 625 in Writing enrollments. It is worth noting that aggregate enrollments for all HASS subjects fall away from last year's 10,724 to 10,096 for 1986-87, accompanied by a subjects/sections drop from 555 to 515. The enrollment total is the lowest in several years.

HASS Concentrations: Patterns of Popularity

Despite some drop from last year's levels, Economics (400 proposed Concentrations) and Foreign Languages and Literatures (398) maintained their clear preeminence as the most populous fields of Concentration. Music (194) and Psychology (190) dislodged Literature (165) from the third spot.

Harvard Cross-Registration

A big decrease (35 to 19) in enrollment in Japanese subjects from last year is a point of interest in the Harvard cross-registration program. This is perhaps due to the establishment of the Japanese language program at MIT. Government subjects had the greatest increase (five to 18) while the most popular field last year, Economics, declined (20 to 12). The total number of students and subjects taken at Harvard remains fairly stable at 175 and 197 respectively.

COURSE XXI

Students: Another Year of Population Growth

By May 1987, combined enrollment in XXI, XXI-K, and XXI-S had risen to 135. The distribution of these students into the ten available humanistic fields followed about the same pattern as last year, with the area of "letters" (Literature, Foreign Languages and Literatures, and Writing) still dominant, although there were encouraging gains in Anthropology/Archaeology and History. Very likely some of this population increase can be attributed to the currency of discussion about liberal studies and "dual competence" at MIT, as well as to recent modifications in admissions policy and practice, but clearly much of the credit should go to the strength of the several faculties and improvements in their curricula.
The number of our majors who are pursuing at least one other degree remained steady at 41, but fell (a bit surprisingly) to 30 percent of the total population.

### Degrees

This was another area of sharp increase. One student received the S.B. in September 1986 (in XXI-S), seven in February 1987 (three in XXI, one in XXI-E, and three in XXI-S), and 36 in June (15 in XXI, seven in XXI-E, and 14 in XXI-S), a total of 44 for the academic year. This more than doubles the 1985-86 total of 21.

### Distinctions

Among the more notable distinctions and honors achieved by Course XXI students this year were:
- Phi Beta Kappa: Ahmad Tabari, William Wedemeyer, Matthew Wiener
- Burchard Scholars: Lisa Greber, Louis Pepe, Sarbani Thakur, David Wallace, William Wedemeyer, Julia White, Matthew Wiener
- Louis Sudler Prize for the Arts: Andrew Borthwick-Leslie
- The Karl Taylor Compton Award: Mark Curtiss
- The William L. Stewart, Jr. Awards: Lisa Greber
- Writing Prizes: Cynthia Closkey, Pat Gabridge, Yu Hasegawa, Scott Lichtman, Michael McIntosh, Terry Simpkins, Dan Urist
- Women's Studies/AMITA Writing Prize: Stephanie Cook, Tamara Kerr, Michael McIntosh, Terry Simpkins.

### Course XXI Alumni Series

The fifth annual presentation in the Course XXI Alumni Series was a concert by the American Reed Trio, featuring John Miller '64, in Kresge Auditorium on Sunday, October 19, 1986. After intermission, Mr. Miller spoke briefly to the audience about the role of Course XXI in his educational experience at MIT, and about his subsequent career as a bassoonist.

TRAVIS MERRITT
The Department of Economics has continued to maintain its unique standing in the profession by the vigorous research of its faculty, their full time attention to undergraduate and graduate teaching and their active participation in important policy-oriented activities in the US and abroad. While making important new senior and junior faculty appointments this year, it was also necessary to rebuff attempts by other universities to entice both senior and junior faculty. The Department also continued to review the organization of all of its teaching programs and added new facilities to improve the access of graduate and undergraduate students to computing equipment. One of the major concerns of the Department continues to be support for its graduate program and new efforts were put into raising funds for this purpose.

Faculty Personnel

Several important new appointments have been made this year. Professor Drew Fudenberg, a leading theorist in the fields of game theory and theoretical industrial organization, who has held an associate professorship at the University of California at Berkeley, has accepted a professorial appointment in the Department. Philippe Aghion and Andrea Shepard, who have completed their graduate studies at Harvard University and Yale University, respectively, will join the Department as assistant professors. Assistant Professor Aghion is an economic theorist and Assistant Professor Shepard works in the field of industrial organization. These new appointments, in conjunction with the existing faculty, give the Department unusual strength in the fields of theoretical and empirical industrial organization.

Professor Jean Tirole was promoted from Associate Professor. Associate Professor Garth Saloner was promoted from Assistant Professor and will hold a joint appointment in the Sloan School of Management. Several distinguished visitors taught in the Department during the year, replacing faculty who were on leave: Professor James Mirrlees of Nuffield College, Oxford University; Professor Eytan Sheshinski of Hebrew University in Jerusalem; and Professor Laura D’Andrea Tyson of the University of California at Berkeley. Professor Martin Weitzman was on leave at Harvard University and Associate Professor Saloner was on leave at the Hoover Institution at Stanford University.

Professor Morris Adelman retired this year after 39 years at MIT and service to the Department. He will be sorely missed in Departmental activities. He will, however, be available in the Center for Energy Policy Research of the Energy Laboratory where he will continue his research activities.

Professor Peter Diamond resigned from the position of Head of the Department and was replaced by Professor Richard Eckaus.

Graduate Student Recruitment and Enrollment

The Department also continues to be successful in attracting the best prospects among graduate students. Approximately 70 per cent of the students who were given awards this year by the National Science Foundation to begin their graduate study in economics will enroll in this department. While testifying to the reputation of the Department, it is also a clear demonstration of the dependence of the Department on the NSF program for support of our students. One of the major reasons for the Department's continuing efforts to raise funds for graduate student support is to have a reserve on which to fall back in case of a significant decline in NSF funding.

The total number of graduate students enrolled has remained approximately constant. There are currently 103 graduate students in residence and 22 non-resident thesis writing students.

Faculty Research

The strength of the Department depends most fundamentally on the intellectual vitality of its faculty as manifest in its research. The productivity of the faculty continues to be high and its interests quite varied. This is indicated in the following examples: "The Wage-Price Spiral," (Professor Olivier Blanchard); "Consumer Differences and Prices in a Search Model," (Professor Diamond); "Exchange Rate Economics," (Professor Rudiger Dornbusch); "How the IMF Lives With Its Conditionality," (Professor Eckaus); "The Analysis of Union Behavior," (Professor Henry Farber);
"International Macroeconomic Policy Coordination," (Professor Stanley Fischer); "Statisticians, Econometricians and Adversary Proceedings," (Professor Frank Fisher); "Piece Rate Incentive Schemes," (Assistant Professor Robert Gibbons); "How Many Doctors Are Enough?" (Associate Professor Jeffrey Harris); "Vertical Integration and the Distribution of Property Rights," (Professor Oliver Hart); "Household Behavior and the Tax Reform Act of 1986," (Professors Jerry Hausman and Jim Poterba); "Incentive Regulation for Electric Utilities," (Professors Paul Joskow and Richard Schmalensee); "Strategic Sectors and International Competition," (Professor Paul Krugman); "Regression-Based Specification Tests of the Multinomial Logit Model," (Professor Dan McFadden); Collective vs. Private Responsibility in the Financing of Public Infrastructure Services," (Professor Jerome Rothenberg); "What Is A Nice Girl Like You Doing In A Place Like This: Macroeconomics After 50 Years," (Professor Robert Solow); "Debt Crisis: North-South, North-North, and In-Between," (Professor Lance Taylor); The Fall of the Bell System: A Study in Politics and Power, (Professor Peter Temin); "Understanding Rent Dissipation: On The Use of Game Theory in Industrial Organization," (Professor Tirole with Professor Fudenberg); "Steady Employment Under Profit Sharing," (Professor Weitzman); "The Cyclical Behavior of the National Office Market," (Associate Professor William Wheaton); "A Capital Asset Pricing Model with Time Varying Covariances," (Assistant Professor Jeffrey Wooldridge, et al).

Faculty Honors

Honors and recognition continue to come to the faculty. They give many outside seminars and lectures and participate intensely in professional activities of which the following are, again, only examples. Professor Diamond gave the Horowitz Lectures in Israel. He and Professor Ann Friedlaender serve as vice-presidents of the American Economics Association. Professor Dornbusch gave the Graham Lectures at Princeton University. Professor Hart was awarded a Guggenheim Fellowship and was invited to serve on the Executive Committee of the Econometric Society. Professor Krugman was elected as a Fellow of the Econometric Society as was Professor Tirole. Professor McFadden continued to serve on the Executive Committee of the American Economics Association and was Chair of the Frisch Prize Committee. Professor Taylor was the Marshall Lecturer at Cambridge University. Professor Poterba received the James L. Barr Award as the outstanding untenured researcher in public economics and the Batterymarch Financial Fellowship. Professor Gibbons was the recipient of the Graduate Student Council Teaching Award.

Research Grants and New Programs

In addition to research grants to individual faculty members, several large grants for research and/or teaching support in particular areas have been received recently. The John M. Olin Foundation has awarded a three year grant to the Department for a program in the Economic Analysis of Law. This grant will support faculty research through released time, student fellowships and a workshop. The major faculty participants will be Professors Diamond, Harris, Hart, and Joskow.

The Pew Charitable Trusts, through its Program for Integrating Economics and National Security, has made an award for the support of the research of Professor Tirole in contracting and dynamic game theory.

The CRB (Charles R. Bronfman) Foundation has funded a Program for the Study of the Israeli Economy that will be directed by Professor Fischer and provide support for research as well as student fellowship support.

Fundraising Activities

The Department has been actively attempting to generate funds for support of graduate students by several different techniques. In April, Professor Dornbusch organized a conference on the international debt crisis with a fee for attendance. A number of the most important international personages involved in the policy issues participated.

The Argentine banking association ADEBA has created a fellowship program for the support of Argentine students who are accepted by the Department for study in the Ph.D. program.

Facilities

A new microcomputer center was created under the leadership of Professors McFadden and Farber and with the donation of equipment by AT&T. This center will facilitate the growing use of computer-based materials in all courses as well as student research and will reduce the substantial computation costs of the Department.
The Economics Department has been directly involved in Project Athena with efforts in two areas. The first is aimed at the use of computers in the undergraduate introductory economics curriculum. Software was developed for use in Introductory Microeconomics (14.01) and Introductory Macroeconomics (14.02). This software was used during the 1984-85 and 1985-86 academic years with mixed results from an educational standpoint.

The second effort is for the use of computers in the undergraduate and graduate statistics and econometrics courses and is currently the primary focus of activity of this type. During the 1985-86 academic year software was developed under the auspices of Project Athena for use in the undergraduate econometrics course. This was quite successful. During the Summer of 1986, the first version of a comprehensive software system for teaching and research in econometrics was developed and put in place on a Project Athena cluster. This system was used this academic year in a number of undergraduate and graduate econometrics courses as well as for undergraduate and graduate thesis work. Work continues to refine and expand the system.

RICHARD S. ECKAUS
The Program faculty continued to become more involved with computers this year when each faculty member received AT&T microcomputers as part of that company's grant to the School of Humanities and Social Sciences; the Program's central computer facility received a great deal of use as students worked on theses and research papers. Special presentations to the Program included a talk on American Indian acculturation by visiting scholar Niels Braroe, and an exceptional evening of talks by Dr. Wylie's class on "Lexington, 1835: A Community in Crisis."

Program faculty continued to be productive in their research endeavors. Three colleagues were in the field: Professor Heather Lechtman in Peru on a mapping and survey of archaeological sites in the Chincha and Pisco valleys, setting up a research facility in Santiago, Chile, at the Museo de Arte Precolombino, and giving a paper on "Early Metallurgy in the Americas" at a conference on early metallurgy held in China; Professor Jean Jackson at the Boston Pain Center studying the building of a therapeutic community; Professor Sharon Traweek at KEK National Laboratory for High Energy Physics in Japan studying the formation of a major new high energy physics facility. Professor Martin Diskin continued his work on ethnic autonomy in Nicaragua by leading an international delegation to visit Miskito refugee camps, testified before congressional sub-committees on agrarian reform in El Salvador, and intensified his research on the demography and economics of Oaxaca. Professor James Howe continued his work on the Marsh Darien Expedition to Panama in 1924-25, and published several papers on aspects of Kuna Indian culture. Professor Arthur Steinberg continued his work on 16th century Venetian painting technique and its relation to culture change, and gave two collaborative papers on ceramic technology in fourth millenium Mesopotamia. Dr. Frederick Wiseman received considerable television and press coverage of his use of pollen studies for the dating and authentication of antiques. Dr. Jonathan Wylie's book The Faroes Islands: Interpretations of History (University Press of Kentucky) was published this year, as were papers on children in field work and the various kinds of laws observed in a Dominican fishing community.

Personnel changes this year included the promotion of Professor Jackson to full professor; the departure of Professor Traweek to Rice University and of Dr. Wiseman and Dr. Wylie to independent research, and the departure of Ms. Marji Berkman as Administrative Assistant. Ms. Alison Salisbury joined the Program as Program Coordinator and Ms. Abby Moser as Program Secretary. Professor Howe succeeded Professor Steinberg as Program Head.

Visitors to the Program included Dr. Niels Braroe who is writing a book on anthropological theory and acculturation; Peter Lacovara from the Egyptian Department at the Boston Museum of Fine Arts who taught a subject on the Archaeology of Egypt; Dr. Lynn Stephen who taught a subject on Sex Roles: A Comparative Perspective, and Dr. Harry Merrick who taught subjects on Human Origins and Approaches to Archaeology.

ARTHUR STEINBERG
The illness and death of Professor Krystyna Pomorska cast a shadow over this year. Her intellectual leadership, her style, and pedagogic mastery will be sorely missed.

Enrollments in the Section have remained relatively stable with total enrollment at approximately 1700. Class size in the language subjects remains fairly high at an average of 17. Undergraduate concentrators in languages and literatures continue to number the second largest humanities concentration. Of our 12 majors this year, two distinguished themselves particularly. One was awarded a fellowship by Duke University to study French Literature, and another received a UROP grant to do research in Germany on the depiction of Nazism in history textbooks.

The three-year experimental Japanese language program was able to expand its offerings in its second year with the addition of Tomoko Graham to the staff as Lecturer. The program enrolled 139 students, more than double last year's figures.

Efforts have continued this year to achieve the curricular integration of languages, culture, and literature within a foreign cultural framework. Curricular modifications have been particularly noteworthy in third semester French and in German literature subjects. Due to the innovative work of our lecturers, Robert Di Donato in German, Gilberte Furstenberg in French, Douglas Morgenstern in Spanish, and Ann Perkins in Russian, with the direction of Professor Claire Kramsch, the language program received national attention this year.

As a member of the Consortium for Language Learning comprised of the Ivy League universities, Stanford, MIT, and the University of Chicago, the Section has received a grant to develop methods and materials to improve the quality of language learning. This grant will complement the work now being done by the Athena Language Learning Project, a $1.4 million effort funded by the Annenberg Foundation and the Corporation for Public Broadcasting. Lecturers Morgenstern and Furstenberg, together with Associate Professor Suzanne Flynn are the key investigators.

This year was a particularly productive one for the Section in the area of scholarly endeavor. Five members of the faculty either published books or had books accepted for publication. Associate Professor Kathryn Crecelius' Family Romances: George Sand's Early Novels is scheduled to be published by Indiana University Press in late 1987; Professor Flynn's A Parameter-Setting Model of L2 Acquisition: Experimental Studies in Anaphora was published by Reidel Press early in 1987; and Associate Professor Elizabeth Garrels' Las Gritas de la Ternura: Nueva lectura de Teresa de la Parra will be issued this year by Monte Avila Editores, Caracas. Associate Professor Edward Turk's substantial work, Child of Paradise: Marcel Carne and the Golden Age of French Cinema, was accepted for publication by Harvard University Press and should appear by the end of the year. Assistant Professor Edith Waldstein's book Bettina von Arnim and the Politics of Romantic Conversation is scheduled for publication by Camden House in the summer of 1987. Articles by faculty appeared or were accepted by the Amsterdamer Beiträge, Canadian Modern Language Review, French Review, Germanic Review, Hispamerica, Journal of Linguistics, Language Learning, Modern Language Journal, Monatshefte. Natural Language and Linguistic Theory, Revista Iberoamericana, Studies in Second Language Acquisition, Studies in the Linguistic Sciences, and the Women in German Yearbook. Essays or chapters authored by faculty appeared in books published by Cambridge University Press, Foris, Giessener Beiträge, and the University of Nebraska Press.

Two noteworthy events were jointly sponsored by the Section. A very successful three-day international symposium on the Spanish Civil War was organized at MIT by Associate Professor Margery Resnick. It brought together veterans of the Lincoln Brigade, survivors of Franco's prisons, and artists and writers from Spain to celebrate the 50th anniversary of the Civil War. The second, a screening of the West German film Stammheim followed by a panel discussion moderated by Associate Professor Michael Geisler, was co-sponsored with the Goethe Institute.

Section members were active this year in Institute affairs, with Professor Flynn a member of the International Issues Group and serving on the Committee on the Undergraduate Writing Requirement; Professor Garrels on the Edgerton Committee; and Professor Catherine Chvany chairing the Phi Beta Kappa selection committee. Professor Kramsch chaired the Foreign Scholarship Committee and served on the Integrated Studies Committee, the School's Equal Opportunity Committee, and the IAP Policy Committee. Professor Resnick chaired the President's Advisory Committee on Women Students' Interests.
The faculty and staff continue their active involvement in the profession. Mr. Di Donato was President of the American Association of Teachers of German; Professor Garrels has been appointed to the Nomination Committee of the Latin American Studies Association; and Professor Kramsch has been appointed to a two-year term with the National Foreign Language Center, and to the Advisory Committee on Foreign Language Programs of the Modern Language Association.

Associate Professor Isabelle de Courtivron and Assistant Professor Joseph Brami will be returning next year from faculty leaves in Paris, and two visiting lecturers will join the Section, Armando Miguelez in Spanish and Michael Knittel in German. Mr. Knittel will replace Mr. Di Donato who, we regret, has resigned. It is a pleasure to report that Professor Flynn has been promoted to the rank of Associate Professor.

CLAIRES J. KRAMSCH
The current year saw the publication of Associate Professor Philip Khoury's *Syria and the French Mandate: The Politics of Arab Nationalism, 1920-1945* (Princeton University Press). By focusing on Syria, whose acknowledged importance in the development of Arab nationalism had not before been the subject of a major scholarly work, Professor Khoury's book constitutes a contribution of extraordinary importance to the history of the Middle East. Comparable pioneering books by two other members of the History Faculty have been written; one has just been published, and the other is scheduled to appear in the fall of 1987. Assistant Professor Peter Perdue's *Examining the Earth: State and Peasant in Hunan, 1500-1850* (Harvard University Press, East Asian Monograph Series), is a study of an important provincial China (Hunan was Chairman Mao's home; its population in 1800 was 18 million) over some four centuries that is built upon archival materials in the People's Republic of China as well as in Taiwan and Japan. Assistant Professor Sarah Deutsch's *No Separate Refuge: Culture, Class, and Gender on an Anglo-Hispanic Frontier in the American Southwest, 1880-1940* (Oxford University Press) tells the story of the Hispanic peoples of Colorado and New Mexico. Founded upon sources in the American Southwest that have for the most part been neglected by all but local historians and written with a particular sensitivity toward the role of women in continuing and extending Hispanic communities through periods of enormous economic and social change, the book, like those of Professors Khoury and Perdue, significantly extends the range of historical knowledge.

Professor Bruce Mazlish, who last year received the Toynbee Prize for distinguished contributions to the social sciences, was this spring appointed the third Thomas Meloy Professor in Rhetoric. Assistant Professor Michael McGerr, who was on leave during the spring of 1987 on an Old Dominion fellowship, was granted a fellowship from the National Endowment for the Humanities -- an honor of increasing rarity -- to work on a book for the Oxford History of the United States on American History from 1900-1930. As a result of the NEH grant, he will be on leave through all of calendar 1988. Professor Pauline Maier was honored by Regis College, which awarded her an honorary doctorate of laws in May.

The academic year 1987-88 will bring on a temporary interruption of the stability of teaching staff characteristic of the past five years. Professor Khoury has been appointed Associate Dean for Academic Affairs in the School of Humanities and Social Science, a half-time position, and will be free from teaching next year. Professor Perdue, promoted to Associate Professor without tenure as of July 1, will become Metcalfe Professor of Engineering and Liberal Arts, which will allow him to teach half-time. Professors Mazlish and David Ralston will each take sabbatical leave, each for one term, in 1987-88; and both Professors Deutsch and McGerr will be on leave in the spring. Professor Robert I. Rotberg, a historian of Africa who has been at MIT since 1968, has accepted appointment as Academic Vice President for Arts, Sciences and Technology at Tufts. As a result of these changes it will be necessary to make part-time junior appointments to teach five of the eighteen subjects which would otherwise not be offered in 1987-88.

Other events of the past year include an Independent Activities Period program that involved 11 of the 13 members of the History Faculty (a lecture series on "War-Torn Cities" was a particular success); memorable lectures under the sponsorship of the History Faculty by Professors Thomas Haskell of Rice, Fred Starr, the president of Oberlin, and Bernard Knox, a veteran of the 11th International Brigade in the Spanish Civil War and former director of Harvard's Center for Hellenic Studies; History's participation, with the Anthropology/Archaeology Program, in further development of a proposed graduate program in the History and Social Study of Science and Technology, for which the Program in Science, Technology, and Society would assume primary responsibility; a special summer course taught by Professor Rotberg entitled "Economics and Politics in Southern Africa: Political Risk Assessment," offered for executives of companies who have investments in South Africa; the intense involvement of several faculty members, particularly Professors Khoury and Maier, in the HASS reform process, and, in general, a participation by members of the History Faculty in Institute committees that was so extensive it would be tedious to summarize. It may be worth noting, however, that scholarly production and service have not proven mutually incompatible. To cite the example only of assistant professors in History, Professor Perdue has been a member of the Committee on Curricula, Professor Deutsch of the Student Affairs Committee, and Professor McGerr (whose book, on American politics in the post-Civil War era, was published by Oxford last year) of the Committee on Academic Performance.

PAULINE MAIER
We begin by striking once again the chord that introduced last year's report: we are pleased that the number of students majoring in literature as either dual or joint majors has continued to grow and this year reaches the number of 34, a figure creditable in a liberal arts college where students are admitted to major in literature and therefore especially creditable at the Institute where the undergraduate role of the humanities is normally a service function for students majoring in other disciplines. Given the receipts by the Faculty of outside awards for funding scholarly leaves of absence, these enrollments pose a problem as well as an occasion for congratulations. The Literature Faculty continues to believe in the importance of the service role of the humanities at the Institute. Nonetheless, we hope that the recent reform in the HASS-D requirement will shift the emphasis of our contribution to the establishment of major and minor programs in literature and a relaxation of some of our share in the burden of distribution teaching.

Meanwhile, we record that the Literature Faculty has continued to increase the recognition of the Institute's contribution to the world of scholarly productivity during the previous year. Its members have published or had accepted for publication articles in such journals as American Film, the American Journal of Philosophy, American Poetry Review, Cinema Journal, Classical Antiquity, Diacritics, the Dickens Studies Annual, Massachusetts Review, Modern Language Studies, Nineteenth-Century Fiction, Prairie Schooner, Renaissance Quarterly, Shakespeare Quarterly, Southwest Review, and Yankee, among others. They have conducted seminars or delivered addresses and papers at learned conferences at the following institutions of higher learning or before the following scholarly organizations: the University of Banff, Boston University, Brandeis, the University of West Berlin, the California Center for the Humanities, the University of California at San Francisco, Columbia University, The Eighteenth-Century Club, the Humanities Studies Association, the National Humanities Center at Durham, Dartmouth College, the University of Massachusetts, the Modern Language Association, Middlebury College, the National Association for Women's Studies, the University of Pennsylvania, San Francisco State College, San Diego State University, the Shakespeare Association, SUNY/Old Westbury, Tufts University, and the University of Virginia. They have had chapters in books devoted to scholarship on the following subjects: the Renaissance stage, the Enlightenment, the history of Homosexuality, nineteenth-century literature, narrative in literature and in television, women in eighteenth-century literature, erotic experience in the ancient world, film criticism and American literature. Two editions of fiction have been prefaced and edited by Professor Cynthia Griffin Wolff, the prize-winning volume of short stories by Associate Professor John Hildebidle has been published by the press of SUNY/Binghamton, and a translation of the love poems of Pablo Neruda by Associate Professor Stephen Tapscott has been published by the University of Texas Press. We also note that two lectures in a series of television cassettes on the Great Books (for university presentation) have been written and produced by one member of the department.

The outset of the academic year was marked by the appearance of Professor Wolff's monumental study of the life and works of Emily Dickinson; the year also saw the publication of Associate Professor Amy Lang's book-length critical study of Anne Hutchinson. Manuscripts accepted for publication include Associate Professor Peter Donaldson's voluminous study on Machiavelli's influence in England, Associate Professor Steven Mullaney's book on Shakespeare's stage, and Assistant Professor Theoharis Theoharis's study of Joyce's theology. We also note with satisfaction the completion of Professor Irene Tayler's book on the Bronte sisters and the extensive Broadway run of Professor A.R. Gurney's latest play, Sweet Sue.

We congratulate Associate Professor David Halperin for the award of a year's fellowship at the Stanford Humanities Center, and Professors Hildebidle and Mullaney for their promotions to the rank of Associate Professor without tenure. Unhappily, we also report the loss of Associate Professor Mullaney to the University of Michigan at Ann Arbor.

Finally: We take pleasure in the receipt by Assistant Professor Theoharis of the Everett Moore Baker Memorial Foundation Award for Excellence in Undergraduate Teaching.

ALVIN C. KIBEL
The Music Section continues to thrive, as evidenced by expanding enrollments, a record-setting 31 gifted students fully or partially supported for private performance study, and increased artistic maturity in our musical groups as the 35-year-old Concert Band became the latest music performance group to gain approval for optional subject credit.

Responsibility for ongoing, progressive leadership of the Section continues to be shared through annual rotation among five professors, enabling each to maintain key professional contacts and pursue the opportunities to remain creative which have brought attention and renown to themselves and the Section. Professor John Harbison will assume responsibility as Section Chair in the upcoming year.

In response to proposals for change in the HASS Requirements, the Music Section reduced its offerings to six 12-unit subjects. As part of this process, our most popular HUM-D subject, 21.60 Introduction to Music, was expanded to include two intensive, interactive lab components in which students will choose either admission by audition to the MIT Choral Society or a combination listening and Athena cluster music computer lab. In addition, Associate Professor Jeanne Bamberger, who is directing the Athena lab component, will also be working with Associate Professor Arthur Steinberg to develop a new cross-disciplinary HASS offering in which issues common to both the appreciation of music and the visual arts are considered. All of these changes and initiatives are understood to be the beginning of a long process which will result in the creation of new subjects and new ways of teaching.

In appearances before the Humanities Visiting Committee and the Provost's Ad Hoc Committee to Review the Arts at MIT, faculty members focused on the issues of overcrowding and inadequate housing which have plagued the Section for many years. They expressed the strong conviction that curricular reforms, increased visibility of the faculty, new options for arts studies, and new recruitment and admissions policies will make already difficult rehearsal, teaching, office, and performance space problems even more acute if they are not addressed responsibly and soon.

As a result of the review process, and after lively discussions with faculty, staff and students, two new steps which will substantively impact the Arts at MIT are being taken. First, upon the recommendation of the Committee to Review the Arts, and with the approval and support of the Provost, Music will combine with Dramashop, Dance Workshop and The Shakespeare Ensemble to become a new Music and Theater Arts Section beginning July 1, 1987. This merger will provide an academic home for Theater Arts within SHSS, greater financial stability, and, after a national search, faculty oversight. Secondly, focus on the evolving role of Music in MIT's artistic mission resulted in new advocacy and support for the artistic endeavors of the Experimental Music Studio as an alternative to pursuing the creation of a graduate program in music. The subsequent commitment of new music resources to sustain the artistic dimension of the Studio--concerts, commissions, residencies--will insure the continued growth of the importance and influence which the facility has earned over the years.

One full year has come and gone into the planning for renovation of a new space. Formerly the Hayden Gallery, soon to be the Elizabeth Parks Killian Hall, the new space will be a much-needed and much-welcomed addition both to Music and other Humanities users. Its features include a seating capacity of up to 150 in at least four possible configurations, moveable hard and soft acoustical surfaces for "tuning" the room, a nine-foot grand piano, harpsichord, audio-visual and recording capability, and flexible lighting. We expect it to be the home of many interesting concerts and lectures.

The Section hosted some 70 concerts, including The Talich quartet from Prague, whose American debut concert in Kresge Auditorium to an audience of 800 was highly praised by audience and critics alike. A very special occasion was the Master Class and performance by MIT Course XXI alumnus John Miller '64 with the American Reed Trio. The event was sponsored jointly by the Music Section and the Course XXI Alumni Lecture Series.

Our Chapel series offered the opportunity to hear artists from as far as The Netherlands, Austria, Switzerland and France, as well as many fine Boston-area ensembles and soloists performing music dating from the Renaissance to 1987. World Music programs of Turkish, Indian and Arab music were featured as well. The concerts were well attended and their varied programs were particularly well received. The MIT Symphony traveled to Amherst and Bridgewater for performances in the Fall and hosted an exchange concert by the Five-College Orchestra of Amherst. In the Spring, the Symphony was guest-conducted by East German conductor Dieter Gerhardt-Wora in its last concert of the year. The MIT Chamber Players under the direction of Professor Marcus Thompson performed Schoenberg's Chamber Symphony, Opus 9 before an appreciative audience in Kresge Auditorium. The MIT Choral Society presented a concert in Kresge Auditorium this Spring after many years of only performing off-campus.
Honors continue to come to Music Section Faculty. Most prominent this year was the awarding of the 1987 Pulitzer Prize in Music, MIT's first, to Professor Harbison, for a new work entitled The Flight into Egypt. The work was commissioned for and premiered by the Cantata Singers at Jordan Hall last November. Professor Harbison was also elected to the American Academy of Arts and Sciences.

Faculty and staff continue to compose, conduct, perform, and lecture worldwide. Assistant Professor Peter Child's String Quartet was premiered by the Lydian Quartet in April. Lecturer Pamela Wood Ambush, the first singer to join us in many years, soloed in a work by Philip Glass with the Israel Philharmonic in Tel Aviv. Professor Marcus Thompson, although chair, still found time to play ten concerts on a Far East tour with the Boston Chamber Music Society. Senior Lecturer John Oliver, who also directs the Tanglewood Festival Chorus, made his debut as guest conductor of the Boston Symphony Orchestra in the World Premiere of The White Island by Martino in April, and also celebrated his tenth year as director of The John Oliver Chorale. Professor Stephen Erdely, violinist and his wife Beatrice, pianist, recorded George Enesco's Third Sonata. Associate Professor Bamberger lectured on her research in Music and Cognition in Mexico, Norway, and Israel. Lecturer Mark Harvey's new Suite for Jazz Orchestra had its premiere performance featuring Jimmy Guiffre at the First Night Festival of the Arts in Boston on New Year's Eve. Lecturer John Corley published six transcriptions for brass choir. Affiliated Artist Jean Rife lectured and appeared in recital as part of the Women in Music series at the University of Wisconsin in Madison.

Associate Professor Lowell Lindgren was on sabbatical doing research in London, and Professor David Epstein continued his work on a new book with a prestigious fellowship from the Alexander von Humboldt Foundation. Professor John Buttrick realized his dream of teaching piano to seasoned players in Switzerland, and Professor Harbison spent the year in residence with the Los Angeles Philharmonic where he served as a strong advocate for the performance of New Music.

Associate Professor Jane Coppock will be leaving after six years of distinguished service. Music Section Secretary Kate Beattie will be leaving to study voice at Boston University, and Orchestra Manager Maureen Burford leaves to pursue ventures in Western Massachusetts. This spring we welcomed Constance Turnburke on board in the new position of Administrative Secretary, a much-needed addition to the Headquarters Staff.

MARCUS A. THOMPSON
The Writing Program performs a vital teaching service at the Institute. The Program's curriculum maintains a depth and balance appropriate for the diverse student population. The current undergraduate subjects in expository writing, creative writing, and science and technical writing draw a steady enrollment of students at all levels, advanced and beginning alike. Many subjects satisfy either phase one or phase two of the Institute Writing Requirement. The cooperative writing subjects for both undergraduate and graduate students, within the various engineering departments, continue to hold their enrollments and are expanding to new departments in the School of Science. This year marked the first MIT class to graduate under the MIT Writing Requirement. Through its work in the cooperative subjects, the Writing Program made significant contributions helping students complete phase two. The summer session course, "Communicating Technical Information," was again popular with many students from industries throughout the world.

In addition to offering an academic curriculum for the student body, the Program brings to the larger MIT community distinguished writers and poets who share their ideas about their work and the craft of writing. Sue Miller, who formerly taught writing at MIT and has subsequently become a best-selling author, read from her recent novel, The Good Mother, together with one of her short stories. The poet and essayist Ishmael Reed lectured on the topic of multi-cultural education. The MIT and larger communities responded enthusiastically to both events.

Two faculty members released new books this year. Senior Lecturer Ilona Karmel's An Estate of Memory, first published in 1969, was reissued last fall in paperback. The biography Rosa Luxemberg: A Life, by Professor Elżbieta Ettinger (Chodakowska), was published last winter and has received world acclaim.

Associate Professor Harriet Ritvo was granted tenure. She will publish a major work on the role of animals in Victorian culture this fall.

James Paradis, Associate Professor, and Edward Barrett, Lecturer, received a grant from Project Athena for the use of computers in their classroom in a technical writing subject.
This year the Department has spent much time and energy on matters of personnel. To retain a faculty of the highest quality, especially in areas related to the burgeoning field of cognitive science, requires constant vigilance. In previous years the Department has reported certain losses. But none need be reported this year, in spite of attractive outside offers. Indeed, it is a pleasure to call attention to the Department's successful efforts to make new appointments, the details of which are given below.

Research: Linguistics

Research in linguistics this year maintained its usual high level of intensity. Among the topics of major interest were: the concept of government, and its unifying role in the system of languages; the theory of lexical knowledge, with special attention to Warlpiri, Miskito, and Winnebago; development of a universal theory of stress and accent; the interrelations of phonology and morphology; studies in the phonology of Spanish and classical Greek; Nicaraguan English.

Research: Philosophy

Research in philosophy this year pursued topics and themes familiar from previous years. Prominent among them were: the foundations of arithmetic and set theory, with special attention to systems in the spirit of Frege's; alleged temporal asymmetries and their relation to physical theories; lexical change and scientific development; psychological explanation, and the nature of so-called narrow content; the foundations of democratic theory; rights, and their relations to risks, liabilities, and responsibilities.

Publications

Institute Professor Noam Chomsky published two books this year: On Power and Ideology (South End Press), and Language and Problems of Knowledge (MIT Press). Also published this year were Asymmetries in Time (Bradford Books/MIT Press) by Professor Paul Horwich, and Rights, Restitution and Risk (Harvard University Press) by Professor Judith Jarvis Thomson. In addition, reflecting individual research interests, journal articles on a variety of subjects were published by members of the Department.

Honors and Awards

Thomas S. Kuhn, Laurance S. Rockefeller Professor of Philosophy, was named President-elect of the Philosophy of Science Association, and Professor Kenneth Hale has been elected to the Executive Committee of the Linguistics Society of America. While in Paris in the spring, Institute Professor Morris Halle was Visiting Professor at the Collège de France. He also gave the Charles Bally Lecture at the University of Geneva, Switzerland.

Leaves of Absence

Professor Thomson, supported by a Guggenheim award, was on leave for the entire year. She was guest lecturer at several universities and participated in a conference on freedom and justice at the Institute for Philosophy, USSR Academy of Sciences, in Moscow. While on leave in the spring, Professor James Higginbotham visited various universities in Europe, spending most of his time at the Scuola Normale Superiore in Pisa, Italy, continuing his research and giving lectures.

Personnel

Professor Judith Wagner DeCew has accepted a position in the Philosophy Department at Clark University.

We are pleased to announce that Professors Higginbotham and Horwich have been promoted to full professor, and Professor Luigi Rizzi has been awarded tenure.

We are also pleased to report that three assistant professors will join the philosophy faculty in the fall: David Brink (ethics and moral philosophy), Michael Hardimon (19th Century German philosophy), and Paul Hoffman (history of philosophy). In addition, Professor Robert Stalnaker has accepted an appointment as professor of philosophy, beginning in the fall of 1988. Professor Stalnaker, currently a member of the faculty at Cornell University, is one of this country's leading philosophers of mind and language.

RICHARD L. CARTWRIGHT
Department of Political Science

Personnel issues have dominated the Department's activities this year. Two factors, the recent loss of several senior faculty members and an unusually large number of tenure decisions, have created openings in traditionally strong fields as well as opportunities to move into previously underrepresented areas. The Personnel Committee, under Professor Myron Weiner's direction, has led an ongoing discussion of departmental needs while at the same time managing searches in five fields with priority status. Because of budgetary constraints, we were intending to make no more than three appointments. As things turned out, searches were successfully concluded in two areas, political theory and Latin American politics. Dr. Uday S. Mehta, a political theorist specializing in British liberal thought of the eighteenth and nineteenth centuries, has been appointed Assistant Professor; he will join Associate Professor Joshua Cohen in teaching history of political thought and philosophy of social science. Also appointed Assistant Professor is Dr. Jonathan Fox, a Latin American specialist whose research has focused on the political economy of Mexico. His arrival will help fill a gap left by the simultaneous departures of Professor Peter Smith, who has accepted a chair in Latin American politics at San Diego, and Associate Professor Brian Smith, who has moved to Ripon College in Wisconsin as the first holder of a chair in Religion, Ethics and Values.

Searches were conducted in three other fields as well - Empirical Methodology, International Relations and Foreign Policy, and Politics and Public Policy. Methodologists with outstanding competence in quantitative methods, modelling, and/or formal theory are in high demand and very short supply; our offer to an excellent prospect lost out to the blandishments of his home institution and an understandable concern about the Greater Boston housing market. In International Relations and Foreign Policy, where the search yielded a somewhat disappointing group of junior candidates, no offer was made. We will resume the search next year at a more senior level. The search in Politics and Public Policy will also continue next year, focusing on the need to replace a departing junior faculty member in the field of science and technology policy. The same motive leads us to plan a search in the broad area of political behavior and communication, where we hope to find an innovative scholar concerned with the analysis of political attitudes, cognitive processes, and modes of communication.

The competition for outstanding political scientists is extremely intense just now, in part because many departments, like our own, are confronting the retirements of faculty members appointed during the expansionist period of the late 1950s and early 1960s. This factor seems to be affecting the market at both senior and junior levels, with scholars of unusual promise or achievement in great demand. We are pleased, in fact, to have made six excellent new appointments over the past three years, one as tenured associate professor, the rest as assistant professors. Our recruitment efforts this year have been particularly sensitive to the need for a thorough and energetic search for highly qualified minority candidates. We made an offer of tenure to a minority scholar at a leading West Coast university, but to our regret the offer was not accepted. The number of minority political scientists, blacks in particular, is quite small, and the pool is growing only slowly. We are developing a roster of potential candidates and will continue the search aggressively.

The Department's most persistent problem remains the inadequacy of our financial aid resources as compared to those of our competitors. For example, whereas the Harvard Government Department offers full support to about two thirds of a typical entering class, we have been able to support only about a quarter of our incoming students. Some of the remainder arrive with grants from outside sources, but many remain too largely dependent on a combination of personal or family resources, loans, and employment at the Institute or elsewhere. So as to improve our ability to compete for exceptionally able students, we have decided to provide tuition and a stipend to about forty percent of the incoming class. This policy is for the most part based not on new resources but on recent procedural changes that have given the Department greater flexibility in the use of existing resources. To some degree, we are shifting to incoming students resources previously used to provide partial tuition assistance to resident post-Generals students writing dissertations. Unless new funds can be found, the risk is that a greater number of advanced graduate students will be obliged to accept non-resident status and take employment outside the Institute, thus slowing progress on their dissertations. We were given a sharp reminder of the importance of these financial issues by the results of a Graduate Student Council survey conducted this year. Whereas Political Science was ranked by its graduate students as one of the top four departments in the Institute with respect to quality of teaching (three of the four, incidentally, were in this School), we found ourselves third from the bottom with respect to adequacy of financial support. The latter result we are determined to do something about.

As always, Department faculty members have turned out an impressive volume of published work. Although it does some injustice to those whose writings have appeared as articles, book chapters, and monographs, we will maintain the custom of allowing a roster of completed books to illustrate the total range of
I am pleased, in conclusion, to report several noteworthy honors and personnel changes of the past year. Associate Professor Richard J. Samuels was awarded tenure this spring. At the Awards Convocation this year, Assistant Professor Brian Smith received the Everett Moore Baker Memorial Award for outstanding teaching. Finally, Professor Weiner was appointed Director of the Center for International Studies, replacing Professor Skolnikoff who has served with distinction in that position since 1972. We are grateful for his services in those years and glad to welcome him back to full-time research and teaching in the Department. The Center has always been, and remains, a critical element in the intellectual environment of the Department, and we are very pleased that Professor Weiner has agreed to commit his large talent and energy to the development of Center research programs, new and old.

DONALD L.M. BLACKMER
Interdisciplinary teaching and educational change were a major focus of faculty effort during the last year. In collaboration with colleagues in the Schools of Engineering and Science, Professors Charles Weiner and M.R. Smith are preparing two of the new interschool context courses. Professor Leon Trilling continued to direct the Integrated Studies Program, in which Professor Smith and Associate Professor Peter Buck taught. Professor Trilling also directs MIT's Second Summer Program and helps lead the New Liberal Arts Program funded by the Sloan Foundation. Interdisciplinary teaching was extensive in the Program: for example, Professor Leo Marx and Associate Professor Louis Buccarelli taught the proseminar of the Technology and Policy Program in the School of Engineering. Associate Professor Sherry Turkle, with Professor Donald Schon of the Department of Urban Studies and Planning, completed a preliminary study of aspects of Project Athena for the Project Athena Study Group. Professor Smith was a member of the Commission on Engineering Undergraduate Education, and will chair a committee on context courses in the School of Humanities and Social Science next year. Professor Kenneth Keniston chaired the Integrative Studies Implementation Committee, charged with advancing the proposals of the committee headed last year by Professor Marx.

The Vannevar Bush Fellowship Program in Science Journalism, directed by Victor McElheny, received a grant from the Knight Foundation of $3 million for long-term support. In recognition of this grant, the largest ever made for a university program for science journalism, the program will be renamed Knight Science Journalism Fellowship Program.

The proposal for a graduate program in the history and social study of science and technology, improved by the involvement of members of the History and Anthropology faculties, was approved by School of Humanities and Social Science Council; it will be submitted to the Committee on Graduate Studies and Programs and to the MIT faculty next fall. At present, STS faculty members are involved in the supervision of 26 graduate theses, largely in Political Science and Urban Studies.

The professional activities of the Program's faculty were varied. Two faculty members play major roles in their respective professional associations: Professor Smith is president-elect of the Society for the History of Technology; Professor Marx is chair of the American Literature section of the Modern Language Association. Professor Marx's two books, The Pilot and the Passenger and The Railroad in American Art (edited with Susan Dauly) will be published in the fall of 1987. Professor Marx is part of the award-winning design team headed by Peter Droge that will rebuild the Japanese city of Kawasachi. Professor Loren Graham chairs the Joint Committee on Soviet Studies of the ACLS/SSRC, and directs the NEH seminar series on Humanistic Dimensions of Science and Technology in the USSR. His book, Science, Philosophy and Human Behavior in the Soviet Union was published in 1987. Associate Professor Emma Rothschild was on leave to be a member of Great Britain's Royal Commission on the Environment. Professor Carl Kaysen was a visitor at the Center for Advanced Studies in Behavioral Sciences in the spring term to work on issues in international security. He stepped down as Director of the Program after five years in that post, and was replaced by Professor Keniston. He plays an active role in many public and private enterprises, e.g., trustee, University of Pennsylvania; board member, Russell Sage Foundation; chair, SSRC Committee on US Foreign Policy Studies; cochair, Institute Committee on the MacArthur Grant. Professor Graham and Associate Professor Turkle both spent extended periods in the Soviet Union, Professor Graham as special advisor for a forthcoming NOVA television program on Soviet science and technology; Associate Professor Turkle as a guest of the Soviet Academy to study the role of computers in the USSR.

The Program continued to provide a base for a number of fellows and visiting scholars. They included Professors Jill Conway (President Emerita, Smith College), Evelyn Keller (Northeastern University), Joan Bromberg (Laser History Project), Jonathan Cooper Smith (History of Soviet electrification), Wu Yuling (Chinese Academy of Social Sciences), Ann Marie Moulin (CNRS, Paris), Dennis Sebian (Mellon Fellow, Boston Water and Sewer Commission), Stephen Weininger (Mellon Fellow, Worcester Polytechnic Institute), and Wolf Shafer (University of Darmstadt).

The Program mourns the death of Professor Robert Morison, whose intelligence, broad experience, and common sense helped guide the Program for many years. A symposium in Dr. Morison's honor is planned for the future.

KENNETH KENISTON
On June 30, 1987, Professor Eugene Skolnikoff (Political Science) left the Directorship of the Center to return to full-time teaching and research. He is only the third Director of the Center since its founding with Max Millikan serving from 1951–1969, Everett Hagen 1969–1972, and Professor Skolnikoff since that time. Professor Myron Weiner (also Political Science) was selected to become Director on July 1, 1988.

Defense policy and arms control continued to be major components of the Center's program. The program is directed by Professor Jack Ruina (Electrical Engineering and Computer Science); also involved are Professors Stephen Meyer, George Rathjens, and Harvey Sapolsky (all Political Science); Steven Miller (Lecturer, Political Science); Dr. Herbert Lin and Dr. Edward Linenthal (Postdoctoral Fellows); Dr. Charles Glaser and William Durch (Research Associates); and Dr. Marc Trachtenberg, Dr. Lynn Eden, and Colonel Don Rakestaw (all Visiting Scholars). Research dealt with the strategic balance, the Strategic Defense Initiative, Soviet defense and arms procurement policy, the Navy in a nuclear environment, and other contemporary defense and arms control issues.

Members of the program were active in public discussion of arms control and defense issues through publications, consultancies, speeches, and participation in professional and citizen groups. The program also conducted in the summer of 1986 the fourth MIT-Harvard Summer Program on Nuclear Weapons and Arms Control for liberal arts teachers; the fifth summer program will be held in 1987. The Center's work on arms control and defense is supported by the Carnegie Corporation, the Ford Foundation, the Hewlett Foundation, as well as the Sloan Foundation, and the US Department of Defense. Support is also provided by MIT through its Fund for International Security and Arms Control.

Closely related was the work supported under the 1984 award to MIT from the John D. and Catherine T. MacArthur Foundation to broaden the base of faculty and student research on international security and arms control. Work was undertaken by Professor Thomas Jordan (Earth, Atmospheric, and Planetary Sciences), Dr. Eric Chivian, MD (MIT Medical Department), Professor Lawrence Susskind (Urban Studies and Planning), Dr. Marvin Miller (Principal Research Scientist, Nuclear Engineering), Professor Sapolsky, Professor Thomas Sheridan (Mechanical Engineering), Associate Professor Philip Khoury (History), Professor Jean Louis (Aeronautics and Astronautics), Professor Aron Bernstein (Physics), and Professor Hayward Alker (Political Science).

The Japan Science and Technology Program continued. With a grant from the Cornelius Van Der Starr Foundation, the program made it possible for MIT students to work as interns in Japanese industrial and university laboratories. With support from the MIT Provost, the program completed a survey of MIT faculty and found a high level of interaction between MIT engineers and scientists and Japanese counterparts and interest in expanding access to Japanese technical publications. During the year efforts were begun to develop an intensive summer course in technical Japanese for American scientists and engineers. A conference will be held in the fall to prepare an analysis for the National Science Foundation on the current status of training programs available for teaching technical Japanese and to recommend ways in which the number of American scientists and engineers trained in technical Japanese and the quality of their training might be raised. The Program is directed by Associate Professor Richard Samuels (Political Science) and Associate Professor D. Eleanor Westney (Management). General support is provided by the Japan Foundation, the US-Japan Friendship Society, the Starr Foundation, and a consortium of American industries: AMF Industries, Eastman Kodak, Ford Motor Company, General Electric, International Business Machines (IBM), Motorola, PPG Industries, Proctor and Gamble, and Teradyne.

Under the direction of Professor Suzanne Berger (Political Science), assisted by Ms. Mitzi Wertheim (IBM, Federal Systems Division) and Captain Jake Stewart, USN (Director of Planning and Assessment, Department of Defense), the first year of Seminar XXI: Foreign Politics and the National Interest was completed. It brought leading area specialists from American and foreign universities to meet with a high-level group of government officials. Funding for the program was provided by the MacArthur Foundation, the Sloan Foundation, the Carnegie Corporation, and the Rockefeller Foundation and by a number of industries: American Telephone and Telegraph International, Boeing Company, Booz-Allen and Hamilton Inc., Gould Inc., Grumman Corporation, Honeywell Corporation, IBM, and the Mitre Corporation. The program will be offered again in 1987–88.
Energy policy remained a research focus. Professor Samuels' study of Japanese and Italian energy policies was published; it was prepared with support from the Endowment for International Energy Studies created with a gift from the Japanese Ministry of Foreign Affairs. Dr. Thomas Neff (Principal Research Scientist) continued exploration of energy markets with funding from the Japan Endowment and the MIT Provost. Professor Skolnikoff began a study of the interaction of science and technology and the international system, examining underlying relationships. His work was funded by the Sloan Foundation and was being carried out in collaboration with the Council on Foreign Relations. Professor Khoury organized for the second year the Emile Bustani lectures on contemporary Middle Eastern issues; the Bustani Family Trust provided support for this well attended series.

Several activities during the year were related to economic and political development. Professors Weiner and Nazli Choucri (Political Science) completed a Ford Foundation funded study of migration in South Asia and in the Middle East. The Center continued to support the Migration and Development Seminar run jointly by Professors Weiner and Oded Stark (Center for Population Studies, Harvard University) and the joint MIT-Harvard Seminar on Political Development, headed by Professors Weiner and Samuel Huntington (Center for International Affairs, Harvard University). The Center also served as the MIT anchor for a joint MIT-Harvard Women and International Development group; a grant from the Ford Foundation helped to support the group. Professor Lance Taylor (Economics), with support from the Ford Foundation, completed work in India and in Brazil on the status of poor countries in the world economy from a structuralist perspective. Food and nutrition policy in the developing countries remained a Center focus of interest. Institute Professor Emeritus Nevin Scrimshaw headed the International Food and Nutrition Program, funded by the United Nations University. Professor Willard Johnson (Political Science) completed his collaborative study with African scholars of communications policy issues in Africa; the work was funded by the Ford Foundation. The Center remained the locus of the Communications Policy Career Development Chair, which supported Associate Professor Russell Neuman (Political Science) and Dr. Charles Jonscher (Lecturer, Management).

The Center continued to sponsor seminars and to issue monographs. As in the past, the Center has been host to visiting American and foreign scholars. The Center has received general support from MIT and from the Exxon Educational Foundation, as well as gifts from individuals.

EUGENE B. SKOLNIKOFF
Integrated Studies Program

Introduction

The Integrated Studies Program (ISP) is designed to appeal especially to students interested in "dual competency" in science or engineering and in the humanities, arts, and social sciences. Now in its third year, ISP is developing a pattern and style well suited to give MIT students an opportunity to explore science and technology and related issues alongside freshman year or departmental requirements.

Statistics

ISP enrollment has grown steadily over the past three years; from 13 and 14 in the Fall and Spring semesters of 1984-85 to 31 and 38 in 1985-86 and 38 and 40 in 1986-87. Our ideal enrollment is 40-50 students, and we expect to be close to that number in the coming academic year.

The ISP group is self-selected. It includes slightly more women than the MIT average, substantially more minority students and several international students. In 1985-86, ISP enrolled 16 women (43%), 8 internationals (21%), and 8 minority students (21%). In 1986-87 the total of 38(F)/40(S) students included 18/14 women (47/35%), 14/18 minorities (37/45%), and 2/4 internationals (5/10%).

While we do not systematically measure the academic performance of our students, their average performance in mathematics, physics and chemistry quizzes appears to be equal to or slightly better than that of the average freshman class. We are proud to note that last year, Franz Drees, one of our students, was awarded the Austin Kelly Prize for a term paper he did in STS 101; this year, two of our 1984-85 alumni, Martha Soto and Alan Szarawarski, were elected Burchard Scholars.

Faculty and Staff

The faculty and staff continuously associated with ISP include Professor Leon Trilling and Anne Armitage, Director and Associate Director of the program. The teaching faculty in mathematics, physics and chemistry are designated on a year-to-year basis by the appropriate departments.

The humanities subjects have been taught by faculty associated with the Program in Science, Technology and Society.

In addition, ISP seminars have been offered by several MIT colleagues. Also we have a staff of tutors, generally ISP alumni/ae and MIT graduate students who are available afternoons, evenings and weekends to work with our students.

Future Development of ISP

At present, ISP combines maximum reliance on mainstream MIT academic activities with an integrating supportive framework provided from within the program: our students attend regular "mainstream" lectures in calculus, physics and chemistry, but attend recitations, humanities subjects, and seminars designed for them within ISP. In the past three years, in addition to these recitations, we have offered one or two Humanities distribution subjects and two to four seminars each term.

In 1987-88 ISP will broaden freshman-year activities, expand our subject offerings, and begin to include upperclassmen in the program in a more formal, systematic way. One goal of this expansion is to encourage students interested in pursuing their professional or pre-professional education with a serious concern about humanistic and social context, to do so coherently, together with like-minded fellows. Another is to develop a locus for developing and testing new curriculum material on a convenient scale under controlled conditions.

After their freshman year, most MIT students place their academic efforts in their departments. ISP will not call on students' academic time to such a degree that it interferes (or seems to interfere) with what is needed to meet departmental requirements. Instead, ISP will focus on those academic activities which are outside the departmental programs—the Institute Science and HASS requirements and some electives in later years.

In 1987-88, our physics and math offerings will continue and tighten the "linkage" we established in our first year and which served as the model for the current efforts sponsored by the Office of the Dean for Undergraduate Education to link sections of mainstream calculus and physics.
The single humanities subjects formerly required of our students each term will be replaced by a "portfolio" of subjects open to all ISP'ers, freshman and upperclass alike. We will thus offer a measure of choice to new ISP freshmen and promote interaction between first-year and upperclass students. To maintain and strengthen a unifying theme of the program we will offer a single seminar. This coming year, the topic will be "The Arts, Science and Technology". In offering this "portfolio" of humanities subjects and this seminar, we hope to develop an interactive ISP faculty from across several disciplines. With some care, the portfolio may be used by some students to fulfill their Humanities Concentration requirements or their HASS minor should they choose to pursue one. ISP also looks forward to including "context subjects" in its core as they are developed and to help carry out double degree programs for those individual students who seek them.

We will continue our expansion of activities during IAP and in our annual speeches series. Discussions with the staffs of Concourse and the Experimental Studies Group during 1985-86 produced jointly-sponsored hands-on activities for credits during IAP 1987. Science Journalism: Writing Feature Articles (in collaboration with the Vannevar Bush Fellows); Automobile Safety Feature Design (in collaboration with the Second Summer Program); and Physics of the Bicycle Wheel (in collaboration with ESG, under the direction of Professor John King).

Our speaker series which grew out of casual conversation but soon became a key event during the Spring term, has provided the focus needed for our "Arts, Science and Technology" seminar. Among our speakers was Mr. Robert Christgau, Rock critic for The Village Voice and current recipient of a Guggenheim Fellowship. Mr. Christgau has expressed a strong interest in returning to ISP during the Fall term to participate in our seminar.

Overall, we feel that ISP has moved past the expected slow start up and is on a much clearer path, both in terms of its internal direction and in terms of relations with the Institute at large.

ANNE ARMITAGE
INTRODUCTION

The Statistics Center was established in 1981 to provide educational and research opportunities for students and faculty interested in statistics. The academic staff of the Statistics Center is drawn mainly from Mathematics, the Sloan School of Management, and Economics. The Statistics Center is under the direction of Professors Daniel McFadden and Roy Welsch. Approximately ten graduate students were enrolled in master’s and doctoral degree programs. There are ten faculty affiliated with the Center, two principal research scientists, and three research scientists.

RESEARCH ACTIVITIES

Statistics

We will briefly summarize ongoing research in Statistics:

Dr. Mai Zhou, an instructor in Applied Mathematics, is working on finding a two-sided bias bound for the Kaplan-Meier estimator and is investigating the asymptotic normality of a synthetic data regression estimator for censored survival data.

Dr. Nicholas Lange, an instructor in Applied Mathematics, is working on random effects models for longitudinal data. He has developed new statistical methods and improved computational procedures for repeated measure designs.

Dr. Greta Ljung, a visiting associate professor in Applied Mathematics, has continued her work in time-series analysis with special emphasis on diagnostic testing, Lagrange multiplier tests, and estimation of missing observations.

Professor Richard Dudley of Pure Mathematics, is working on the theory of empirical processes. He has also developed a new test for multivariate normality and is continuing his work on genotype-environment interactions.

Dr. Peter Kempthorne, a National Science Foundation Postdoctoral Fellow on leave from Harvard, spent the past year working on multiple-objective and group decision making, influence analysis in statistical modeling, and statistical modeling in financial economics. Professor Kempthorne will be joining the MIT faculty next year as an associate professor in the Sloan School.

Professor Welsch of the Sloan School continued his work on high-breakdown robust regression (in association with a student, Alan Zaslavsky), and background plots for regression diagnostics (with Lisa Newton, a Research Associate at the Statistics Center).

Econometrics

Housing decisions of the elderly have been investigated by a research group led by Professor McFadden. Working with the Panel Study on Income Dynamics and the linked tapes of the Annual Housing Survey, this group has investigated the questions of the transactions costs faced by the elderly, the prevalence of "liquidity traps" in which the elderly are "house-rich and cash-poor", and the heterogeneity of tastes. Henry Pollakowski has carried out calculations of hedonic prices for housing by region and time. Axel Boersch-Supan and Mike Tamada have analyzed the composition of households, identifying and linking through time decision-making units. Brian Palmer has worked on continuous-time models of mobility. Johnathan Feinstein and Professor McFadden have estimated heterogeneous Markov models of mobility and tenure choice. This research has produced several papers presented in March at a National Bureau of Economic Research conference on the economics of aging, and additional research reports and a thesis by Mike Tamada are in progress.

Hidehiko Ichimura has been investigating the asymptotic properties of estimators for the projection pursuit model, under the direction of Professor McFadden. His work has included Monte Carlo investigation of his estimators using Statistics Center resources, as well as the Cornell supercomputer.

Professor McFadden has been doing research on methods of simulated moments estimation for computationally intractable problems, along with research assistants Dan Nelson and Chungrund Ai.
Professor Henry Farber has been using Statistics Center computing facilities in continuing investigations of the duration of unemployment.

Danny Quah, Assistant Professor in Economics, has been carrying out studies of the behavior of macro-economic time-series, with particular attention to international linkages. He has installed the Regression Analysis of Time Series software at the Statistics Center. Takeo Hoshi has worked with him.

Concurrent Computing

The Concurrent Computing Group consists of Patrick Barton, Elizabeth Ducot, Virginia Klema, and associated students.

During the past year work has continued on building a hardware/software environment to support research on numerical algorithms and scientific applications in a concurrent computing environment. In particular we have focused on three distinct machine architectures from the point of view of supplying an environment that permits the user with a scientific application to design top-down specifications that can be transported among the three systems.

The hardware available for this research within the Concurrent Computing Laboratory includes: a number of custom built "manager-worker" concurrent systems, a 32-node Intel hypercube, and a small Bolt, Beranek and Newman (BBN) Butterfly development system on loan from BBN. A SUN 260/C is a communication device, a file server and graphics engine for the concurrent environment. Two additional SUN 3/50's complete the inhouse resources of the Concurrent Computing Laboratory, all nodes of which are linked together via a local area network. A key characteristic of the hardware from the point of view of this research is that all nodes, whether network nodes, system hosts, or elements within the concurrent systems, support the Institute of Electrical and Electronic Engineers (IEEE) standard for binary floating point arithmetic in hardware. For testing and evaluation of larger problems, we have been given access to large Butterfly machines as well as an 8-processor TX Alliant.

Although all configurations within the laboratory are tightly coupled, multiple instruction multiple data, homogeneous systems, they exemplify three distinct architectures: shared memory with Banyan network interconnect (BBN Butterfly), private memory with hypercube interconnect (Intel Hypercube), and dual-ported memory with multibus interconnect (manager-worker systems). Moreover, they encompass two distinct programming paradigms: coordination of cooperating sequential processes with communication via message passing, and generation of computational tasks as required with management of common memory.

Ongoing research toward the development of an appropriate supporting environment to serve these diverse architectures continues at both the node library and operating system interface levels. The basic linear algebra modules that form the basis for higher level mathematical software and that are suitable for use in the various node libraries are being designed and implemented. Trap handlers for error recovery in the event of arithmetic exceptions are being developed, as are the mechanisms for generating error reports and debugging information. Strategies for node-node, host-node and node-host communication and monitoring also provide an active area of research.

As our research progresses, the resulting environment is tested within the context of two distinct classes of scientific applications: one is that "parallel certain" as exemplified by many computationally intensive statistical methods, and another such as the algorithms used in computational fluid dynamics in which the algorithmic decomposition strategies are less obvious.

SEMINARS

Nine major seminars were given this year. Professor David Pollard from the Department of Statistics, Yale University, gave a talk entitled "The Asymptotics of Estimators Defined by Optimization." Professor Burton Singer of the School of Public Health and Biostatistics Department at Yale gave three lectures: "Drug-Resistant Malaria: An Integration of Genetics and Epidemiology," "A Reconsideration of Heterogeneity Modeling, with Economic Applications," and "Mathematical and Statistical Issues in the Analysis of Longitudinal Surveys." Dr. William S. Krasker, who received his Ph.D from MIT (Economics) and is now at Salomon Brothers, gave a lecture on "Statistics, Operations Research and Wall Street." Professor Peter Bickel from the Department of Statistics at Berkeley spoke on "Efficient Estimation of Dimensional Parameters Based on 'Maximum Likelihood' Ideas." Dr. Ross Ihaka, an Assistant Professor of Statistics at Yale, gave a talk on "A Computer Language for Introductory Data Analysis Courses," and Professor Roger Koenker of the Department of Economics at the University of Illinois-Urbana gave a talk entitled "L-Estimation for Linear Models."

The Statistics Center also had the following Independent Activities Period (IAP) schedule:


FUTURE DIRECTIONS

This year, due to the transfer of the Center from the School of Science to the School of Humanities and Social Sciences and the addition of Professor McFadden (Professor of Economics) as Co-Director, the Statistics Center has broadened its activities to include econometrics and other social sciences. It retains its strong links to management, mathematics, and civil engineering. Efforts to hire a new faculty member to be associated with Whitaker College were turned down by the Provost's office.

We were successful in replacing Professor Tony Wong, who resigned from the Sloan School, with Dr. Kempthorne formerly of Harvard University.

Efforts to find a new senior mathematical statistician in Applied Mathematics again proved unsuccessful. This has caused us to keep our Ph.D student population low. Every effort should be made to fill this position in 1987-88.

Late this year, we began the search process for a new senior statistician to be supported equally by the Sloan School and the Department of Economics. Our goal is to fill this position in 1987-88 with someone who can become Director of the Statistics Center not long after his or her arrival at MIT, and then take an active role in the development of statistics at MIT.

We have received a grant from Project Athena to hire an Athena developer/coordinator for statistical computing. This person (an offer has been made) will reside in the Statistics Center and will be concerned with the development and acquisition of statistical software for the Athena workstations. He will also help to train faculty members and teaching assistants in the use of the software. This should correct a weakness in the Athena applications software base.

DANIEL MCFADDEN
ROY E. WELSCH
Women's Studies

The academic year 1986-87 was the third full year of operation of the Women's Studies Program. The Program has so far been distinguished by an ever-growing curriculum, an increasing number of involved faculty, and a strong base of student support and interest. In the summer of 1986, the Ad Hoc Review Committee issued its report on the Program, concluding that "The MIT Women's Studies Program is considered to be of very high quality." Further, the Committee pointed out that, "Given MIT's current efforts at curricular reform, the interdisciplinary nature of the Program, the concern for diversity, the rethinking of the role of ethics and social values in a professional education...make the Program timely for MIT and important to the education of all students."

CURRICULUM

Ten Women's Studies subjects were offered in 1986-87, enrolling over 200 students. "Gender and Science", taught by Visiting Professor Evelyn Fox Keller, was again one of the most popular subjects offered, attracting more than 30 graduate and undergraduate students. "American Women's History", taught by Assistant Professor Sarah Deutsch, enrolled almost 60 students. Two new subjects were taught this year, and both were extremely well received by students: "Virgin, Harlot, Hysteric: Visual Imagery of Women in Nineteenth Century Culture", taught by Assistant Professor Anne Wagner, and "Reproductive Biology", taught by Professor Nancy Hopkins. The "Reproductive Biology" material lends itself readily to a synthesis of humanistic and scientific perspectives, such as the Institute has tried to effect for over a decade. For this reason, the Biology Department, and others interested in pedagogical liaisons between the schools, have been closely following the attempts made in "Reproductive Biology" to ground scientific and technological discussions of reproduction in their moral, social, and political contexts.

The "Introduction to Women's Studies" subject included, for the first time, a computer component. Students used an interactive game, developed under Project Athena, to probe gender-based behavior assumptions. The program will be refined based on student response this year, and will become part of the regular Women's Studies introductory class.

STUDENTS

At the end of the school year, Women's Studies had 18 concentrators, and five majors.

Three UROP students worked with the Women's Studies office in the past year to add to the bibliographies we have on file. These bibliographies are a major resource for Women's Studies scholars and students, and are much in demand. As a result of this year's UROP work, we can now add annotated bibliographies on these subjects to our existing collection: "Eating Disorders", "Women and Technology", and "Asian Women."

In conjunction with AMITA the Program is sponsoring a student project to record the oral histories of past women graduates from MIT. Work will start on this in the summer of 1987, and should continue next year.

Three graduating students wrote Course XXI Theses in Women's Studies.

RESOURCES

The Women's Studies Reading Room continues to be heavily used, and the collection is rapidly growing: it now includes over 1500 titles and 40 journals. The non-circulating subject files maintained in the Women's Studies office are also much in demand.

Two sets of papers from Women's Studies conferences were prepared for publication, and will appear in late 1987.

MIT Women's Studies Program is one of the largest in the Boston area, and an informal part of our agenda has been to serve as a "clearinghouse" for Women's Studies events, and to maintain contact with other Women's Studies programs in the area. To facilitate this, we produce a twice-semester newsletter, "Women's Studies Around Boston", which is mailed to more than 800 people.

The "clearinghouse" arrangement is to be formalized in the coming year. The Program received a small grant from the Ford Foundation to begin to plan a Boston-area consortium of Women's Studies. There will be tremendous advantages in combining the resources of scholars in the wider Women's Studies community.
A donation from an alumnus, together with a contribution from AMITA, enabled the Program this year to offer a Writing Prize in Women's Studies.

PROGRAMS AND SPECIAL EVENTS

As before, Women's Studies this year sponsored a number of events that drew audiences from MIT and from the community. In the Fall, the Program co-sponsored with Anthropology a film and speakers series on "Women and Technology in the Third World" that was attended by over 100 people. It also co-sponsored a screening of the award-winning film, "Las Madres", that drew a packed audience of 200, and two other film events on campus: an evening of British feminist experimental film, and an IAP film series on women's international efforts to secure civil, reproductive, and property rights. In addition to the film series, the Program sponsored three other IAP events, all of them well attended: a prose and poetry reading by Associate Professor Amy Lang and Assistant Professor Robin Becker; a lecture series on the history of American feminism by Visiting Scholar Jill Conway; and, a seminar on "Women and the Urban Environment." Toward the end of the year, the Program co-sponsored a lecture by a visiting Indian scholar, Vandanna Shiva, on the topic of "Women and Ecology."

The major event of the year was our three-week series of films, lectures, and workshops entitled "Asian Women in Two Worlds", distinguishing among the cultural realities of women's lives in South Korea, China, Vietnam, Japan, and the Philippines. The conference was planned with the hope that it would be of interest to the many Asian and Asian-American women at MIT and to the rest of the student body. More than 700 people attended, and the conference drew considerable media attention. By focusing on minority women both within and outside MIT, we created a network of people and tapped a constituency that does not usually think of MIT as an ally. There was considerable good-will generated by this conference.

The Program was brought into a consortium of schools receiving funds from the Ford Foundation to introduce (in some cases) and improve (in other cases) the representation of gender issues in the curriculum. As a result, next year on campus the Program will sponsor: with the Urban Studies Department, a faculty workshop series on introducing gender studies into the Planning curriculum; a faculty development workshop for science and engineering faculty on campus who want to use the new scholarship on gender and science to develop new subjects in this field; and, curriculum development money for Lecturer Caroline Whitbeck to work on her new subject on ethical issues in medical technology.

RESEARCH AND PUBLICATIONS


Senior Lecturer Ruth Perry, Director of the Program, received a Guggenheim Fellowship, which she will take during the coming year. Her project is: "The Contribution of Gender to the Formation of the English Novel, 1750-1815." Effective July 1, 1987, Dr. Perry will become a tenured, full Professor.

We were pleased to host a Visiting Scholar from West Germany, Elisabeth Kremer, doing historical research on the symbolic relations of gender and technology. Next year, there will be another Visiting Scholar here, working on feminist perspectives on ethical issues in the development of technology.

Women's Studies faculty participated in the major conferences on feminist scholarship this year: the Berkshire Conference on the History of Women (Wellesley College), the National Women's Studies Association conference (Spelman College), and the Third International Interdisciplinary Congress on Women (Trinity College, Dublin).

RUTH PERRY
The principal major activities of the Sloan School continue to focus on research dealing with important management issues and on the education of both practicing and potential management professionals and of the educators of the next generation of management professionals and researchers.

The following sections report on the School's teaching programs and research during the past year and on the broad array of related professional activities in which the School's faculty and staff have engaged in that same period.

Our undergraduate program, but principally our master's program and executive education programs, are our principal opportunities for affecting the quality and practice of management, not only in this country but in others, through the dissemination of our own and many others' ideas impinging on that practice.

Our doctoral program is aimed essentially at the training of future educators of management professionals and at training these persons to engage in the serious research which must underlie any successful efforts at professional education.

Our research activities have continued to seek to create and replenish intellectual capital as the basis for understanding the resolution of important management issues, not just in relation to today's headline perspectives but geared for the longer term and thrust.

All of these activities continue to merit the high national and international repute of the School's programs and research.

All of us have also continued to regard ourselves as extraordinarily fortunate in having the opportunity to work with persons throughout MIT who have both understood and who are sympathetic to the School's efforts in continuing to press for the attainment of a clear leadership role in addressing some of the complex managerial problems of our times and of the future.

The School's Annual Report published each year describes in more detail an update on the School's progress in our teaching and research programs and in our other activities. This report provides a somewhat less extensive summary of the School's annual activities during the 1986-87 year.

TEACHING PROGRAMS

Undergraduate Program

This spring the Sloan School graduated its first class in the new undergraduate program in Management Science. Of the 43 seniors who were graduated during the year, 18 chose an option in Information Systems, eight selected Marketing Research, five chose Operations Research, and three selected Behavioral Science. The remaining nine students followed other specially approved options.

Five of our graduates also received bachelor's degrees from the Department of Electrical Engineering and Computer Science, two from the Department of Mathematics, and one from the Department of Civil Engineering.

As can be seen from Figure 1, the introduction of the Management Science curriculum three years ago has been accompanied by a significant increase in undergraduate enrollment at the Sloan School. One hundred thirteen students were enrolled at Sloan this spring, in addition to 19 others who were enrolled in Management Science as their second SB department. (Enrollment figures are based on the Registrar's fifth-week counts.)
Seventy-two of our continuing undergraduates have declared their options as follows:

**Regular Options**
- Information Systems 27
- Operations Research 7
- Marketing Research 6
- Behavioral Science 7

**Special Options**
- Finance 23
- Health Care Management 1
- Legal Studies 1

**Total Declared** 72

Because of the strong interest in Finance as a special option, the Undergraduate Program Committee has begun consideration of adding Finance as a regular option. This will be explored more fully during the next academic year.

As shown in Figure 2, a substantial—and steadily growing—number of students from other MIT degree programs enroll in our undergraduate subjects. There were 574 such enrollments during the 1986-87 academic year, representing the classroom equivalent of 63 full-time (48 units)—at-Sloan undergraduates. Since a Sloan undergraduate actually takes only about 60 percent of his or her units at Sloan, this is equivalent to having approximately 105 additional Sloan undergraduates in our program.
Faculty participation in MIT's Independent Activities Period (IAP) in January has also been increasing steadily for the past several years. This year 42 percent of the Sloan School faculty participated. As shown in Figure 3, Sloan faculty participation has almost quadrupled since 1983. The number of scheduled events has increased from 20 two years ago to 36 this year. Once again, our most popular series was "A Brief Introduction to Management," which drew a total audience of around 200. The speakers in the series this year were Professors William F. Pounds, Stewart C. Myers, and Stuart E. Madnick.

The Undergraduate Management Game was offered during IAP for the sixth time. It now carries three units of academic credit.

Increased enrollment required enlarging the Undergraduate Program Committee to provide more faculty advisors. Further enlarging will be required for next year. Professors Thomas J. Allen, Robert M. Freund, Stephen C. Graves, Thomas W. Malone, and James B. Orlin, Drs. Stan N. Finkelstein and Jeffrey A. Meldman, and Hillary De Baun served as undergraduate advisors. Professor John D. Sterman served as coordinator of MIT's Undergraduate Research Opportunities Program. Dr. Meldman chaired the Undergraduate Program Committee and served as coordinator of the Sloan School's IAP activities.

Ms. De Baun joined the Sloan School in August as Coordinator of the Undergraduate Program.
The master's core curriculum, in this second year since its revision, has proven successful in achieving the goals the faculty established for it in 1984. Further refinements this year included the concerted efforts of core faculty to balance the workload schedule so that assignments and examinations were evenly spaced, smoothing out the "peaks and valleys" to allow students better use of study time. With the new core well established, attention was also directed towards enhancing the quality and scope of elective offerings and initiating several new concentrations which address areas of current concern in management, such as "Applied Economics and Marketing."

Response to the Distinguished Speakers Series was quite enthusiastic, again necessitating the use of closed-circuit coverage so that all those interested could participate in the presentations. Chosen by a board of master's students, this year's speakers were J. Willard Marriott, Jr., Chairman and President, Marriott Corporation; John G. McElwee, Chairman and Chief Executive Officer, John Hancock Mutual Life Insurance Company; John F. Akers, Chairman of the Board, IBM; and Paul E. Raether, General Partner, Kohlberg Kravis Roberts and Company.

Several new scholarships became available to master's students during this past year. The Little Family Foundation offered Junior Achievers Fellowships to support management education for people who had developed an interest in business through the Junior Achievement program. Both first- and second-year students were eligible and the winners this year were Denis R. Cagna, Timothy D. Connors, Elana T. Lichtenhant, Alan S. Orloff, Timothy J. Seelaus, and Phillip S. Yoo. The Unisys Corporation initiated a scholarship program for first-year students, based on academic merit and leadership involvement at Sloan, and awards were presented to Marla Choslovsky and Douglas M. Leone. Latsis Scholarships, established by Dr. Spiro J. Latsis and his family to provide fellowship assistance to academically superior graduate students of Greek descent, were bestowed upon Thomas L. Pappas, Ioannis A. Pierides, and Michael G. Thoukidides.
Special awards for academic excellence and professional promise were made to several second-year master's students. The Sloan School was proud to name Jennifer J. Bailey as the first Miriam Sherburne Scholar. The funding for this scholarship was established by the alumni/ae of the School in recognition of Miss Sherburne's 50 years of devoted service. Henry B. du Pont III Scholarships, which were established by the Crestlea Foundation with a gift from the late Mr. du Pont, were bestowed upon Thomas A. Bowers and Hoyt L. Davidson. James F. Dondero was named the Alexander Proudfoot-Howard J. Samuels Memorial Fellow for 1986-87. This award is given annually by the Alexander Proudfoot Company in honor of Mr. Samuels, a former Proudfoot director and longtime friend of MIT. In 1978 the Ford Motor Company Fund established the Henry Ford II Scholarship, which this year was received by Gustavo A. Pierini. Thomas R. Rosen was awarded the Thomas M. Hill Prize, given for excellence by a second-year student in the field of accounting. This award was established by the late Professor Hill's friends and colleagues to honor his memory and his 30 years of distinguished service to the Sloan School.

Thomas C. Cronin and Allen R. Frechter were named Seley Scholars, awards established by the late Louis E. Seley and Mrs. Seley to honor graduating master's students for outstanding academic achievement and exceptional promise of business leadership. The Brooks Prize was established by E. Pennell Brooks, first Dean of the Sloan School, to honor the author of the best master's thesis. Beatrice E.H. Ballini and Jamie Henson received the award for the 1985-86 academic year; their co-authored thesis, "Quincy Shipyard: Valuation of the Yard for Industrial Water Dependent Uses," was supervised by Professor John Parsons. Honorable mention was given to Moyo C. Kamgaing for his thesis entitled "Optimal Hedging Under Price, Quantity, and Exchange Rate Uncertainty." Professor Parsons also supervised this thesis.

Sloan School nominee Lisa A. Epstein was chosen by the American Marketing Association to receive the George H. Brown Marketing Scholar Award as the top marketing student in the country.

Although the number of applications for admission increased yet again this year, we chose to limit the size of the entering class to 186, feeling that a smaller class would lead to less crowded classrooms and a higher quality educational experience.

The following table presents a profile of the graduating classes of 1987 and 1988.

<table>
<thead>
<tr>
<th>Profile of Graduating Master's Classes</th>
<th>1987</th>
<th>1988*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Candidates</td>
<td>215</td>
<td>186</td>
</tr>
<tr>
<td>US Citizens</td>
<td>165</td>
<td>131</td>
</tr>
<tr>
<td>Foreign Citizens</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Women</td>
<td>43</td>
<td>38</td>
</tr>
<tr>
<td>Members of Minority Groups</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Median GMAT Score (national average is approximately 460)</td>
<td>650</td>
<td>660</td>
</tr>
<tr>
<td>Undergraduate Grade-Point Average (out of 5.0)</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Undergraduate Majors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Sciences and Humanities</td>
<td>35%</td>
<td>33%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>19%</td>
<td>16%</td>
</tr>
<tr>
<td>Engineering</td>
<td>31%</td>
<td>38%</td>
</tr>
<tr>
<td>Pre-Professional</td>
<td>15%</td>
<td>13%</td>
</tr>
<tr>
<td>Average Years Full-Time Work Experience</td>
<td>3.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Age at Admission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 23 years</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>23-24</td>
<td>32%</td>
<td>27%</td>
</tr>
<tr>
<td>25-26</td>
<td>25%</td>
<td>28%</td>
</tr>
<tr>
<td>27-28</td>
<td>17%</td>
<td>20%</td>
</tr>
<tr>
<td>29 and over</td>
<td>17%</td>
<td>17%</td>
</tr>
</tbody>
</table>

* Projected
The Placement Office reported a banner hiring year for Sloan School master's candidates. Employer interest in management students remains strong, with investment banks and consulting firms currently competing most actively to secure permanent and summer employees. Seventy-two organizations (up from 52 in 1985-86) scheduled fall semester presentations to inform students of available career opportunities. A total of 163 firms subsequently interviewed Sloan candidates during the winter and spring. This figure represents a slight increase in activity, despite a drop in on-campus recruiting reported by some other leading MBA programs this year.

By June 1, more than 80 percent of the graduating class had accepted employment. As in 1986, the highest percentage of students (42 percent) selected financial positions, up 6 percent from last year. Consulting and marketing roles were next in popularity, attracting 17 percent and 12 percent of the class, respectively. The majority of Sloan graduates will work in either New York City (35 percent) or Boston (34 percent). California proved to be the third most attractive location, with 12 percent of the class accepting assignments there.

Investment banks surfaced as the top "consumer" of 1987 graduates at 25 percent of the class, followed closely by consulting firms at 20 percent. Commercial banks and other financial service organizations account for another 17 percent of student hires. On the manufacturing side, electronics firms led the way at 10 percent (down slightly from last year's figures). Chemical/pharmaceutical companies ranked #2 in manufacturing sector placements, increasing from 4 percent of the 1986 class to 8 percent of the 1987 class.

For the first time in four years, the percentage of students entering manufacturing firms rose slightly. Graduates selecting service sector positions remains very high (72 percent), but at least the tide of students moving toward service industries appears stemmed for the present.

Students reported that, on average, they interviewed beyond the initial screening interview with seven companies. From these interviews, students generated from one to eight offers, with most individuals receiving multiple offers before making their final selections. Some students reported only one offer because they secured their top priority position early in the process and terminated their search accordingly.

Base salaries accepted by the Class of 1987 ranged from $24,000-$80,000, with a median of $50,000. Sixty-one percent of the graduates also reported some form of guaranteed bonus as part of their compensation package, with a median bonus of $10,000 offered.

The Master's Program Committee, chaired by Professor Gordon M. Kaufman, continued its evaluation and refinement of the revised master's core, introduced a year ago. Dr. Jeffrey A. Barks, Associate Dean for Master's and Bachelor's Programs, again provided imaginative and effective administrative leadership for the master's program. Margaret Daniels Tyler directed our admissions effort with flair and efficiency, making the task of attracting and evaluating all those applicants look much easier than it is. David A. Weber joined the staff as Director of Master's Student Services. A Sloan graduate himself (1983), Mr. Weber added a special understanding of the needs of our students to the office staff. Lucinda Hill continued in her role as Master's Program Coordinator, as well as assuming considerable responsibility for our alumni/ae affairs program for master's graduates. Miriam Sherburne and Harriet Barnett, both of whom served Sloan for many years as full-time employees, are now continuing to help the master's program as part-time advisors, counseling current students, and meeting with prospective degree candidates.

Management of Technology Program

The Management of Technology Program was established in 1981 at MIT and is the only program of its kind. Administered by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to a Master of Science in the Management of Technology. It is aimed at engineers and scientists with five to 10 years of work experience, and strives to prepare these professionals for more senior roles in industry and government where they will generate and manage technology-based endeavors.

Program structure and a new curriculum were developed originally by a joint faculty committee from both the Sloan School and the School of Engineering. The curriculum includes an intensive core of analytic subjects taken during the summer and at least eight subjects allowing intensive study of the management of technical people and programs. Subjects in Managing Professionals, Marketing/Technology Interface, Technology Strategy, and Manufacturing/Technology Interface have attracted enthusiastic registration from graduate students throughout MIT, as well as from program students. All program attendees also write a thesis in the area of the management of technology, and company-sponsored individuals in particular find the thesis a golden opportunity to explore in great depth some issues of chief corporate concern.

The Management of Technology Program was conceived originally by the Faculty Program Chairman, Professor Edward B. Roberts of the Sloan School, and the late Herbert Hollomon, Professor in the MIT School of Engineering. A new Program Director, Mario Gnecco, was hired this year, reporting to Alan F. White, the Sloan School's Associate Dean for Executive Education. Ably assisting him has been Jacalyn Walker-Sharp, Program Coordinator. From a pilot class of six students, the program expanded to 28 for the 1986-87
class. Plans are to continue expanding gradually toward 40-50 students per year. Though required to have at least five years of work experience before coming to the program, students average closer to 10-12 years of experience and tend to be in their mid-30s in age. They come from a wide variety of fields, including aerospace, electronics, research and development, and the military. Less than a third of each class has been foreign, with representation from several countries in Europe, also China, Japan, Israel, Argentina, and Singapore. Most students are financially supported in the program by their organization.

Discussions have been underway during the past year with faculty of both Schools regarding addition of a Management of Manufacturing Systems track to the MOT Program. It is hoped that new subjects can be developed that would permit initiation of this option in June 1988.

The PhD Program

During 1986-87, the Sloan School's doctoral program maintained its prominent position in the face of continuing intense competition from the other leading business schools. From 292 applications we made 42 admission offers and had 21 acceptances, acceptances that were widely distributed across our 13 concentrations:

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Numbers and Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managerial Economics</td>
<td>2 (1 foreign, male; 1 US, male)</td>
</tr>
<tr>
<td>Finance</td>
<td>3 foreign, male</td>
</tr>
<tr>
<td>Accounting</td>
<td>1 foreign, male</td>
</tr>
<tr>
<td>Industrial Relations</td>
<td>2 (1 US, male; 1 US, female)</td>
</tr>
<tr>
<td>International Management</td>
<td>2 (1 foreign, male; 1 US, female)</td>
</tr>
<tr>
<td>Management of Technological Innovation</td>
<td>2 (1 foreign, male; 1 US, male)</td>
</tr>
<tr>
<td>Strategy and Policy</td>
<td>2 (1 foreign, male; 1 US, female)</td>
</tr>
<tr>
<td>System Dynamics</td>
<td>2 US, male</td>
</tr>
<tr>
<td>Organization Studies</td>
<td>2 US, male</td>
</tr>
<tr>
<td>Management Information Systems</td>
<td>2 US, male</td>
</tr>
<tr>
<td>Operations Management</td>
<td>1 US, male</td>
</tr>
</tbody>
</table>

While the overall percentage of US applicants remained at approximately 39 percent, the foreign applications rose to 61 percent, reflecting increases across all countries, including the large number of applications normally received from India, Asia, and Korea. We continue to cooperate with the efforts of the American Assembly of Collegiate Schools of Business (AACSB) to recruit more qualified US applicants, and work on our own strategies for identifying prospects and sources. During the academic year 1984–85, the PhD Program Committee initiated a marketing/recruiting effort to generate applicants we might otherwise miss and included in the application form the question, “How did you hear about our program?” Of the 238 responses, no less than 40 percent indicated professors and a sizable 20 percent, publications. These figures underscore the importance of faculty participation and visibility in exciting the interest of good students.

The bulk of the program's graduates pursue academic careers. Of the 18 graduates in 1986-87, no less than 13 embarked on such careers at Harvard, MIT, and Boston University, to name a few. The remaining five have accepted or are considering non-university positions.

The Doctoral Program Committee, headed by Professor Arnold I. Barnett and coordinated by Sharon Cayley, has successfully grappled with the diverse problems of a very individualized program, including reducing the median time taken to complete the program (four and a half years) through early research ties to faculty, and a considerably enhanced financial aid package. For the first time in some years we are able to make financial awards much more competitive with our principal rivals.

Alfred P. Sloan Fellows Program

On June 1, 1987, 55 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1987 reflected a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad. The Sloan Fellows Program was the first executive education program in the United States, and is now in its 56th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Asia. They visited with leading government and industrial representatives in the People's Republic of China, Hong Kong, Japan, and Singapore.
A comparison of the Class of 1986-87 with previous classes follows:

<table>
<thead>
<tr>
<th></th>
<th>78-79</th>
<th>79-80</th>
<th>80-81</th>
<th>81-82</th>
<th>82-83</th>
<th>83-84</th>
<th>84-85</th>
<th>85-86</th>
<th>86-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>31</td>
<td>30</td>
<td>31</td>
<td>30</td>
<td>28</td>
<td>26</td>
<td>30</td>
<td>26</td>
<td>31</td>
</tr>
<tr>
<td>International</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>15</td>
<td>13</td>
<td>15</td>
<td>13</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Government</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>International</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World Bank</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Municipal Management</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Medical Management</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Church Management</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>University Management:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>International</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>World Bank</td>
<td>54</td>
<td>56</td>
<td>56</td>
<td>55</td>
<td>55</td>
<td>56</td>
<td>57</td>
<td>54</td>
<td>55</td>
</tr>
</tbody>
</table>

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 12, 1987, the Class of 1987-88 arrived; there are 56 participants in the 1987-88 program.

The Director of the Sloan Fellows Program, Alan F. White, is an alumnus of the program (Class of 1971) and once again performed efficiently and effectively in a very challenging role. Professor Robert B. McKersie served as chairman of the faculty program committee.

**Program for Senior Executives**

In the spring of 1987, the program completed its 63rd session. The program continues to attract outstanding senior executives from private and public organizations around the world, with approximately one-half the participants coming from overseas.

The new Director of the program is Dr. Charles R. Grader, who took over from Dr. Edwin C. Nevis during the summer of 1986. Professor Henry D. Jacoby continues as chairman of the faculty committee.

**Greater Boston Executive Program**

Continuing to serve as an important link between MIT and the Boston area community, the Greater Boston Executive Program enrolled 22 participants in the 1987 session held from January 30 to May 8.

The executives, 16 men and six women, met each Friday for 15 weeks for sessions on economics, finance, accounting and control, human resource management, marketing, and strategic planning offered by the Sloan School faculty.

**Summer Programs**

During the 1987 Summer Session, Sloan School faculty participated in nine Special Summer Programs.

Six of the programs were of one-week duration. The Management of Research, Development and Technology-Based Innovation, conducted by Professor Edward B. Roberts, continued as a two-week program and again attracted a large audience. Managerial Decision Making, offered for the second summer by Professor John S. Carroll, was limited to two days.

Three of the one-week programs were held as live-in programs at the MIT Endicott House and Conference Center in Dedham: The Executive Program in Financial Management, coordinated by Professor Myers; Operations Management, chaired by Dr. Harlan C. Meal; and Corporate Strategy, coordinated by Professor Arnoldo C. Hax.
The remaining programs had all been offered in previous Summer Sessions: Medical Technology Assessment for Health Professionals (Dr. Finkelstein); Corporate Planning and Control Systems (Dr. Morris McInnes); Corporate and Economic Policy Design with Microcomputers: A System Dynamics Approach (Professor Sterman and David P. Kreutzer); and Operations Management in the Service Industries (directed by Professors Richard C. Larson and Amedeo R. Odoni of the Operations Research Center, and assisted by Professor Gabriel R. Bitran).

In addition to these programs offered as part of the Institute's Special Summer Programs, several members of the faculty and staff directed and participated in two other sessions. The Center for Information Systems Research offered its 11th annual summer meeting seminar on Managing Information Technology: New Responsibilities in a Changing Environment at the Hyatt Regency in Cambridge. In July, several Sloan School faculty helped conduct a one-week seminar on Logistics Analysis for Carriers and Shippers, sponsored by MIT's Center for Transportation Studies.

Industrial Liaison Symposia
Sloan School faculty and staff also participated in several of the Industrial Liaison Symposia held during the year. In December, Professor Michael S. Scott Morton spoke on Definition, History and Applications: Decision Support Systems, Expert Systems and Expert Support Systems at a symposium on Expert Systems from the User's Perspective. In March, Dr. Heldman spoke on the Legal Protection of Information at a symposium on Security of Computer and Telecommunications Systems; and in May, at a symposium on Hazardous Substances Management: The MIT Approach, Professor J. Daniel Nyhart spoke on Perspectives and Approaches to Liability issues. The symposia were all held in Cambridge.

RESEARCH
This section summarizes the major research efforts and accomplishments of the School. This work is both disciplinary and multi-disciplinary in character and is grouped here under three main headings corresponding to the major clusters within which the School's faculty are currently organized: Economics, Finance, and Accounting; Management Science; and Behavioral and Policy Sciences Areas. The section does not include detailed references to the substantial research efforts and participation of the Sloan School faculty and staff in the activities of many of the Institute's interdepartmental centers or laboratories. These are described in the separate center or laboratory reports.

Economics, Finance, and Accounting
Faculty research in Economics, Finance, and Accounting applies the tools of economic theory, statistics, and operations research to a wide range of applications. Work is directed to economic policy issues, to pure theory, to empirical issues, and to the development of improved decision-making procedures for corporate managers.

Applied Economics. Professor Ernst R. Berndt continued work in the areas of technical change, capacity utilization, and the response of firms' production programs to changes in input prices. He collaborated with David Wood, Director for the Center for Energy Policy Research, on energy price-induced changes in capital utilization and capital valuation. He investigated the measurement of economic capacity utilization in multi-product firms, and international comparisons of multi-factor productivity growth.

Professor Kenneth A. Froot's research concentrates on international economics and finance, including capital asset pricing in an international setting and the determinants of exchange rates. He has completed work on optimal programs of trade liberalization, and undertaken new tests of possible excessive volatility in exchange rates and stock prices.

Professor Henry D. Jacoby's primary research is the analysis of energy and resource projects using methods of derivative asset valuation. He focuses on the development of methods appropriate for projects facing volatile oil prices and complex non-proportionalities in the determinants of project cash flows. The main application is to oil tax regimes.

Visiting Professor Charles D. Kolstad collaborated with Professor Berndt on research aimed at identifying the separate contributions of embodied and disembodied technical progress. They are also developing measures of the effects on costs and productivity of differences in the investment behavior of manufacturing firms in the United States, Japan, and West Germany.

Professor Robert S. Pindyck continued his work on the nature and implications of capital risk in the United States economy. He examined the effects of price and cost uncertainty on investment capacity choice, output, and pricing. A new project will examine the value of commodity storage and its dependence upon quantity or price volatility, as well as the role of storage in short-run price determination.

Professor Nancy L. Rose has explored the role of motor-carrier deregulation on labor compensation. She has recently begun a major research program in regulation and risk-taking by firms, and she is investigating the effect of airline deregulation on airline safety.
Professor Julio J. Rotemberg continued work with Professor Garth Saloner, of the MIT Economics Department, on the interface between macroeconomics and the strategic interaction between firms and workers. He has begun a new research endeavor on the determinants of the level of public debt. He has also worked with Professor Pindyck on the interrelationships between movements and futures prices for different commodities.

Professor Richard L. Schmalensee's research interests are in the areas of regulation, anti-trust policy, and industrial organization. He collaborated with Professor Paul Joskow, of the MIT Economics Department, on a study of the theory of design of regulatory institutions and mechanisms, with application to recent developments in the electric utility industry. He also studied recent developments in merger policy and in empirical work on industrial organization.

Professor Thomas M. Stoker was on sabbatical leave as Visiting Professor of Economics at Universität Bonn, and as Visiting Research Fellow at Nuffield College, Oxford University. He proposed and developed new methods for non-parametrically characterizing statistical relationships and testing behavioral restrictions of econometric models. He also studied the impact of heterogeneity in consumers on properties of general economic equilibrium.

Professor Lester C. Thurow continued his research on productivity growth in the United States and on the implications of large federal budget and balance of payment deficits for economic policy. He was appointed the Sloan School's next dean, succeeding Dean Abraham J. Siegel.

Finance. Aside from his work with Professor Chi-fu Huang (described below), Professor John C. Cox began work on the application of game theory to the valuation of convertible bonds and other corporate securities with contractual provisions that allow exchange for other securities. He has begun work on a new version of his book, Options Markets, with his co-author, Professor Mark Rubinstein, of the University of California, Berkeley.

Professor Daniel M. Holland continued on an inter-industry team preparing a major tax reform for Jamaica. He has addressed the taxation of companies and real property.

Professor Huang's research mainly concentrated in three areas: continuous-time stopping games, optimal-consumption and portfolio policies in continuous-time models, and the theory of competitive bidding with a resale market. He worked with Professor Lode Li, of the Management Science Area, to prove the general existence of a Nash equilibrium in a class of continuous-time, non-zero sum games, where the strategies of the players are in the space of stopping times. He has collaborated with Professor Cox on optimal consumption and portfolio policies in a continuous-time economy.

Professor Robert C. Merton continued his research on the pricing of fixed-income securities and related options and futures-type contracts. He also continued his joint research with Professor Terry Marsh, of the University of California, Berkeley, on dividend behavior of firms. Professor Merton completed his term as President of the American Finance Association. His Presidential Address considered modifications to standard capital asset pricing models induced by incomplete information.

Institute Professor Franco Modigliani has been concerned with several analytical issues in macroeconomics and with a number of macroeconomic policy problems. He continued his research into the role of bequests and transfers in the formation of aggregate wealth, and on the effects of deficit financing and the national debt of the United States economy. He studied the problems of unemployment and economic stagnation in Europe, and the potential for cooperation and coordination of macroeconomic policies.

Professors Stewart C. Myers and Richard S. Ruback completed a paper, "Discounting Rules for Risky Cash Flows," which shows how to calculate the market value of a risky asset by discounting the asset's cash flow by weighted average of the after-tax treasury rate and the expected return on the market portfolio. The discounting procedure works under any equilibrium theory debt on taxes. Professor Myers worked with Saman Majd, of Yale University, on a paper applying option pricing theory to sequential capital investment decisions.

In addition to his work with Professor Myers, Professor Ruback continued research on the market for corporate control, including takeover defenses and the effects on target shareholders of successful control contests. He completed a paper analyzing the economics of dual-voting class shares.

Professor John E. Parsons spent the spring 1987 semester at the University of Economics and the Academy of Sciences in the German Democratic Republic, continuing his research on countertrade arrangements and capital financing arrangements in socialist economies. He also analyzed long-term supply contracts in the international natural gas market.

Visiting Professor Scott F. Richard studied existence theory as applied to new models of information in equilibrium capital asset pricing models under uncertainty.
Visiting Professor Stavros B. Thomadakis completed a paper on the determinants of Tobin's q-ratio in cross-sectional samples of firms, including the effects of barriers to entry and exit. He also investigated the valuation effects of tender offers in the light of contingent claims created by the bids. Professor Thomadakis has a long-standing interest in the Greek economy, and has completed a study of early post-war policies of monetary stabilization in that country.

Accounting. Professor Ravi Bhushan has investigated the collection of information about publicly traded firms. He also collaborated with Professor Froot on a study of the non-contemporary correlations of common stock returns.

Visiting Professor Frank J. Fabozzi's research generally concerns corporate financing methods and pricing of traded securities. He edited books on equipment leasing, municipal bonds, money-market instruments, and mortgage-backed securities.

Professor Paul M. Healy collaborated with Professor Krishna Palepu of the Harvard Business School on papers examining whether firms' decisions to initiate or omit dividend payments or to issue new common shares convey information about the firm's future earnings performance. They found that firms which initiate or admit a dividend payments have abnormal earnings changes for several years subsequent to the dividend announcement. On the other hand, firms that announce common stock offerings do not exhibit unusual earnings.

Professor Patricia C. O'Brien's research is concentrated in two areas. The first concerns the formation of market expectations about firms' futures earnings; the second concerns shareholders' voting on matters of corporate governance. The research on earnings expectations examines predictions of firms' earnings made by financial analysts and portfolio managers.

Management Science

At every turn these days—from the popular and business press to congressional hearings and reports from our national academies of engineering and science—the nation demonstrates how absorbed it has become with the subject of industrial competitiveness. The issues are far-reaching: how can the country sustain its industrial preeminence, exploit its competitive edge in arenas such as computer and information technology, and improve its industrial and manufacturing infrastructure? Technological innovation is certainly a key ingredient of the competitive balance sheet; but so is the management of technology. For example, one recent study concluded that over 85 percent of the substantial labor differential between the United States and Japan in the production of compact automobiles is attributable to better management systems.

One of the hallmarks of the Management Science Area is its long-standing commitment to improving managerial practice through the design and study of managerial systems. Its contributions include new models, methods of analysis, and managerial approaches for improving practice in many domains of management—manufacturing, logistics, and marketing of new products, often through the conceptualization and design of new managerial instruments such as decision support and expert systems.

This past year the area has continued this research thrust. Much of its efforts have been conducted in collaboration with several complementary activities at MIT, including the School's Center for Information Systems Research and Management in the Nineties Program, and the Institute's Artificial Intelligence Laboratory, Center for Transportation Studies, Operations Research Center, and Statistics Center. In addition, the area, along with the School of Engineering, has embarked upon a major and ambitious educational and research program entitled Leaders in Manufacturing.

The following discussion, organized around the area's four subgroups, provides a capsule summary of the faculty's research.

Marketing. Marketing at MIT has always been distinguished by its emphasis on quantitative model building and integration of theory with managerial practice. The research this past year continued in this tradition and expanded to include more behavioral science issues.

Professor Frank R. Kardes, with a PhD in Psychology, joined the group this past year. His research includes work in consumer judgment and memory, relationships between individual attitude and behavior, and casual inference in individual perception. Professor Kardes joined Professor Deborah L. Marlino as faculty in the area of consumer behavior. They are jointly investigating cognitive processing as a mediator of the effects of persuasion. Independently, Professor Marlino has been examining simplifying heuristics that consumers use when forming product judgments and the behavioral basis of the advantages of pioneer market entries in gaining market share. Professors Kardes, Marlino, and Glen L. Urban are jointly studying the effects of communication on the product categorization and evaluation of a new product. Professor Urban has also continued his empirical investigation of order of entry effects by the use of time series/cross-sectional methods and the development of market research methods to identify lead users and improve the productivity of new product design. Professor Urban and Professor John R. Hauser are collaborating on a model of consumer purchasing of durable products using premarket forecasting of automobiles as a testbed. Professor Hauser's own research focuses on issues of marketing competition.
He has completed a study of price, positioning, and advertising decisions in a competitive environment. Professor John D.C. Little examined brand choice models that are calibrated by household panel data collected by optical scanners in supermarkets. In particular, he developed a new method for measuring the effect of coupons on incremental sales. Dean Alvin J. Silk, in addition to his responsibilities as Deputy Dean, continued to work on detecting attitude shifts in advertising field experiments and on strategic alternatives in creative advertising policy.

**Management Information Systems.** The management information systems group continues its focus on how organizations can capitalize on the extraordinarily rapid changes in the costs and capabilities of information technology. The group’s diverse research ranges from technological issues concerning artificial intelligence and data base architectures to behavioral issues related to group communication and end-user computing.

Professor Randall Davis’s research has continued to focus on understanding and reasoning about how things work and how this knowledge is used in the design of expert systems. He has studied expert systems that design products for testability, and artificial intelligence ideas related to learning from experience. Professor John C. Henderson examined the value of information systems in identifying opportunities for strategic information systems. He has also studied how computer-aided planning and design tools impact managerial and design processes and affect design team performance and group decision making. Professor Thomas W. Malone’s research focused on designing computer systems that help groups of people work together, including such topics as expert systems for intelligent information sharing and computer-mediated group decision making. He also continued to work on theories of organizational structure and on the impact of information technology on organizational structure. Dr. John F. Rockart continued to study a variety of issues related to management use of information resources. Based upon several extensive field studies, he has proposed conceptual frameworks for management of data resources, executive support systems, and the role of the line manager in information systems. Professor Michael E. Treacy pursued his research on assessing the impact of information systems on the performance and the cost structure of the firm. As part of this research he has been conducting a major field study with a large-scale sales force. In a collaborative research effort, Dr. Amar Gupta, Dr. Hoo-Min Toong, and Professor Stuart E. Madnick continued their efforts to develop innovative multi-processor computer architectures for storing extremely large data bases. Dr. Gupta and Professor Madnick also initiated a new study to develop methods for integrating heterogeneous data bases that enable intelligent retrieval of information stored on multiple systems. During this year, Professor Madnick also edited a book on strategic uses of information systems and completed a book on project management, and Dr. Gupta published two books on microprocessors.

**Operations Management.** During this past year, the operations management group has continued to work closely with industrial sponsors. The group’s research program, supported primarily by the private sector, has continued its traditional thrust in manufacturing, but has now expanded to encompass service industries. The strong ties with industry have permitted the group both to contribute to practice in several applied settings and to enrich its research agenda.

The operations management group’s varied research encompasses a number of studies. Professor Charles H. Fine has continued to work on quality control and quality improvement and on the economics of flexible manufacturing technologies. He has also begun to examine the effects of cost accounting practices on decision making in manufacturing. Professor Lode Li, jointly with Professor Fine, has been developing models for product life cycles and technology choices. They are extending existing theory to include automated flexible production technologies and are in the process of completing work on stopping games including theory and application to market entry and exit of firms. Professor Li has also been working on the management of flexible production resources. Professor Gabriel R. Bitran has continued to develop manufacturing models for the semiconductor industry, including the study of processing of both silicon and gallium arsenide materials. Professor Bitran has also been studying several underlying methodological issues, including networks of queues as applied to the design and management of wafer processing, and vacation queues that arise in situations with shared resources. He is also investigating solution heuristics for product grouping in group technology problems. In a recently completed industry-sponsored project, Professors Fine and Stephen C. Graves and Dr. Harlan C. Meal developed and applied an aggregate flow model for tactical planning for the assembly and testing of electronic components. Professor Graves has recently begun a similar project on tactical planning for a financial services operation. Professor Graves, working with colleagues at the C. S. Draper Laboratory, continued work developing decision support aids for the design of the assembly systems.

**Operations Research and Statistics.** Operations research and statistics seek to develop new models and methods for decision making and to apply this technology to a variety of managerial problem settings. Research at MIT is noted for its balance between theory and practice. The group’s activities this past year demonstrate this style of research.

Professor Arnold I. Barnett continued several investigations of applied probabilistic modeling concerning aviation safety, criminal behavior, and prison population forecasting. In addition, he completed more of his introductory textbook on applied probability and statistics. Professor Gordon M. Kaufman continued his study of finite population sampling methods with particular attention to the development of estimators.
for successively sampled populations. This theory has applications to primary energy resource projections and to probabilistic characterization of software reliability. Professor Roy E. Welsch continued his research on high breakdown regression diagnostics and estimation for nonlinear exponential family models, including work on graphical methods.

In the field of mathematical programming, Professor Robert M. Freund has studied methodological and algorithmic issues in linear and nonlinear programming, fixed point theory, and the increasingly popular subject of projective transformations. He has also been conducting research concerning optimization methods for classes of location problems. Professor James B. Orlin developed new results for a variety of problems in combinatorial and network optimization jointly with Professor Ravindra K. Ahuja, a visitor from India. Professor Orlin's research includes the fastest known algorithms for several network flow problems and an algorithm for the emergency sealift scheduling problem developed for the Military Sealift Command with Professor Psaraftis of the Department of Ocean Engineering. Professor Jeremy F. Shapiro has continued to develop and implement a variety of mathematical programming-based decision support systems in such diverse application settings as financial portfolio selection, manufacturing, and industrial logistics. Professor Thomas L. Magnanti has studied methods for designing and analyzing networks in the problem settings of facility location, production planning and scheduling, communication systems, and urban traffic planning. Much of this effort has been devoted to optimization of large-scale systems.

Personnel. After Professor Edwin Kuh's death in June 1986, Professor Welsch became Acting Director of the Center for Computational Research in Economics and Management Science. Professor Daniel McFadden of the Department of Economics has joined him as Codirector of the Statistics Center, replacing Professor Herman Chernoff. After 10 years of service, Professor Shapiro stepped down as Codirector of the Operations Research Center. Professor Magnanti replaced him and now serves as Codirector with Professor Amedeo Odoni of the Departments of Aeronautics and Astronautics and Civil Engineering.

Several members of the Management Science Area received honors this past year. Professor Freund was named the Elisha Gray II Career Development Assistant Professor of Management Science; Professor Davis was presented the Artificial Intelligence award from the Boston Computer Society; Professor Madnick received a Graduate Student Council teaching award; Professor Welsch was elected a fellow of the American Association for the Advancement of Science; and Professor Magnanti was elected vice-president/president-elect of the Operations Research Society of America.

Behavioral and Policy Sciences

The faculty of the Behavioral and Policy Sciences Area deal with a broad range of managerial issues, ranging from context-specific subjects like international management, technological innovation, and human resource management through process activities such as strategy and policy and on into the disciplinary foundations of management, such as organization studies and the behavioral theories of individual decision making. Through this diversity run certain unifying themes. In particular, the area faculty consistently employ the research methodologies of the behavioral sciences and, from their individual vantage points, they all display a continuing concern for policy issues.

The structure of the area fosters cross-disciplinary research and the past year contains a number of important examples. Most striking is the Management in the Nineties project directed by Professor Michael S. Scott Morton of the strategy and policy group. The project, now finishing its third of five years, is a five-million-dollar research effort sponsored by a consortium of companies and government agencies. It is examining the changing nature and content of management as affected by the new information technologies. The research team draws from the whole School but contains major efforts by the Behavioral and Policy Sciences faculty. Included are members from strategy and policy, organization studies, industrial relations, international management, and technological innovation.

Any classification of the faculty's research requires a certain amount of arbitrariness because of the overlap and intermixing of subject matter. In the descriptions that follow we shall try to point out some of the inter-connections. For example, human issues are central to the management of an organization and similarly critical to the relation of organizations to each other and to their economic, social, and political environment. The faculty in organization studies and industrial relations have their primary research in these areas and frequently have overlapping and complementary interests, particularly on the subject of human resource management.

Organization studies faculty are concerned with understanding the relation between the individual and the organization and the dynamics of behavior in organizations. Professor John E. Van Maanen is well along on a book, to be called "Tales of the Field," that draws extensively on his own experiences in writing ethnography. Separately, he has expanded his research on the "management of emotions," which is typified by the task of an organization like Disneyland, which, through its employees and physical surroundings, seeks to provide a happy experience for its customers. Professor Edgar H. Schein, working with Research Associate Diane Wilson under support from the Management in the Nineties project, has initiated a study of CEO's assumptions about information technology (IT). Does the CEO use IT directly? What are his views of the role of IT in his company? What problems, if any, has he had with IT? Data have been collected from more than 75 CEOs and are now being analyzed.
While on leave in the UK, Professor Lotte Bailyn has been continuing her Management in the Nineties sponsored research on work done at home and in other locations away from conventional supervision. She finds widespread resistance by managers to work at home because of their preference for "visible" employees. Professor John S. Carroll is studying judgment and decision-making behavior in negotiating tasks with a specific focus on the way negotiators understand their opponents' thinking. This work is being supported by the National Science Foundation's Decision, Risk, and Management Sciences Program. As part of the Management in the Nineties project, Professor Carroll is also studying the introduction of microcomputers in large corporations at two company sites. His concern is with the impact of expectations on implementation strategy and process.

The research of Professor Don N. Kleinmuntz emphasizes the interaction between descriptive and prescriptive theories of individual decision making. In particular he is focusing on dynamic tasks, i.e., decisions characterized by repeated choices with feedback between them.

Professor Deborah L. Ancona is dealing with the question of how groups in organizations adapt to their environments and, in particular, how they manage the boundaries between themselves and other parts of their organizations or the external world. She has been working with new product teams in high-technology companies to explore their boundary management behavior in resource dependent environments and how this influences group effectiveness. Professor Robert J. Thomas is starting a study of alternative approaches to the design and implementation of new technology. He observes that innovative forms of employee participation and organizational design appear to be essential for economic competitiveness and employment security. Further, although workers' input to the design of the technology they are to use may be desirable, the obstacles to effective interaction are many. Professor Thomas's initial steps are to understand the processes involved, lay out a framework for addressing the issues, and acquire sites for longitudinal case studies.

In the other part of the Behavioral and Policy Sciences Area that specializes in human issues, the human resource management and industrial relations subgroup, the major book from the Sloan Foundation/Labor Department--supported research was published this year: "The Transformation of American Industrial Relations" by Professors Thomas A. Kochan and Robert B. McKersie, along with Professor Harry Katz of Cornell. Professors Kochan and McKersie are continuing their study of the staying power of various types of industrial relations innovations.

Professor Lisa M. Lynch has been doing research on employment and unemployment of young people in the US using data from the National Longitudinal Survey. She finds, for example, that young males have reduced chances of finding successful employment the longer they remain unemployed, but that more completed years of schooling and private (as opposed to governmental) training programs significantly increase the probability of becoming re-employed. The labor market experiences of nonwhite and white males and females are also distinctly different. In another direction Professor Lynch and Visiting Professor Paul Osterman have undertaken a new project with Management in the Nineties sponsorship on the impact of technological innovation on employment in telecommunications. Using an extensive longitudinal personnel data set from Bell South, they are doing a first-of-its-kind study of the interaction of technical change with the evolution of internal labor markets over a six-year period, looking at such questions as whether the new technologies are employment displacing or employment enhancing.

Although officially retired, Professor Phyllis A. Wallace continued work on her manuscript summarizing her 10-year longitudinal study of 360 Sloan School graduates from the five classes, 1975-79, and, in addition, is about to assume the presidency of the Industrial Relations Research Association. It is a pleasure to note that a conference and festschrift honoring Professor Wallace took place in June 1987.

Adjunct Professor Mary F. Rowe continues her work on the structure and function of corporate ombudsman offices and other non-union complaint systems.

System Dynamics. The System Dynamics National Model of economic behavior has occupied the major attention of the group over the past several years. The model itself is now substantially complete and the focus of activity has changed to writing a series of books that describe the model and the insights that have come out of it. Work on the national model has been conducted by Professor Jay W. Forrester, Professor John Sterman, and Research Associates Peter M. Senge and Alan K. Graham.

In new work Professor Sterman has turned his attention to the theoretical and empirical foundations for simulation modeling of decision-making behavior. This requires relating aggregate decision rules in simulation models to micro empirical knowledge developed in behavioral decision theory and other behavioral science. Using a direct experimental approach, he has examined several microcomputer-based capital investment games with a diverse sample of subjects. Their pattern of decisions over time compares closely with that of the formal rule used in an aggregate level simulation model. This direction of research is of considerable interest in behavioral decision theory where there has been little investigation of dynamic effects. In other work he has been testing the adaptive learning model often used in system dynamics to represent the effect of expectations. Using historical data on public forecasts of several types of time series, including energy demand, inflation, and oil resources, he finds that his aggregate rules reproduce the forecasts well.
Management of Technology. Much national attention has now been focused on technology as a source of new products and improved manufacturing productivity. Questions of managing technological innovation, capturing its benefits, and incorporating technological change into company strategy has taken on increased importance in an era of stiff global competition. Professor Eric A. von Hippel has been doing research and writing on several of these topics. During the year he completed his project with Professor Urban of the marketing group on their concept of 'lead users' as a source of information for evaluating radical new product concepts. They have shown that a manufacturing firm, in this case one dealing with computer-aided design, can specify a field of interest, find lead users in it, and obtain from them high-value marketing research information. In another direction Professor von Hippel is discovering that diffusion of technical know-how is facilitated to a surprising degree by the trading of proprietary information by engineers in competing firms. He further has developed models that explain why this takes place.

In another Management in the Nineties sponsored project, Professor Thomas J. Allen has conducted research in which the communication patterns of 750 software engineers have been monitored for a period of 18 months while their communication capabilities via personal computer work stations and networks have been gradually improved. He is also following up, under NSF sponsorship, the career progress of a group of engineers and managers in an R&D laboratory studied six years ago.

Biomedical enterprises have been the focus of certain work by Professor Edward B. Roberts which is now in its final publication stages. He continues his research in areas of new product strategies of young high-technology companies as well as on new venture strategies of large companies.

Strategy and Policy. The advent of heightened domestic and international competition in the business world has caused corporations to put more emphasis on strategic issues. Within the Sloan School a surprising number of faculty with disciplinary backgrounds have, over the past few years, become interested in the strategic problems of the firm. Several of these have moved to the strategy and policy subgroup where they have been joined by young faculty hired directly into the field. Because of the wide interest within the School, the core group is interconnected well with such other areas as organization studies, international management, marketing, finance, and the management of technology.

Professor Arnoldo C. Hax's work this past year has been oriented toward expanding our understanding of large number of intertwined issues including strategies for growth and diversification, mergers and acquisitions, global management, the value chain and competitive advantage, and the linkage between horizontal strategies and vertical integration.

As mentioned earlier, Professor Scott Morton is director of the Management in the Nineties project. Within it he has personally focused his own research on the impact of electronic data interchange, particularly on the question of who ends up capturing the economic benefits. In addition he has been collecting data on a series of implementations of expert systems being used as working support tools for white-collar workers. His interest is in seeing where such systems can be of real impact and what classes of work and workers will be affected.

Professor Arnoldo C. Hax's work this past year has been oriented toward expanding our understanding of a large number of intertwined issues including strategies for growth and diversification, mergers and acquisitions, global management, the value chain and competitive advantage, and the linkage between horizontal strategies and vertical integration.

Professor Mel Horwitch has completed a major book manuscript, "Post-Modern Management: Its Emergence and Meaning for Strategy," in which he reviews and interprets the evolution of general management thinking over the past 25 years. He has also continued to develop his research on technology strategy and its increasing importance, especially in technology-based industries.

The research of Professor N. Venkatraman focuses, in part, on the issues of measurement in strategy research, that is, the schemes necessary to link verbalizations of theories to empirical operationalizations. This work includes the development of measures to describe the strategic orientation of a firm and the operationalization of business performance from a strategic perspective. In addition, Professor Venkatraman has been studying the interfaces between strategic management and information technology. He currently has a project underway to study strategic response to technological discontinuities in the tax services market as part of the Management in the Nineties program. Professor Michael A. Cusumano is concerned with the application of manufacturing-type approaches to large-scale software development in the US and Japan. He is particularly interested in the degree to which it may be possible to improve the effectiveness of engineering organizations through the use of organizational strategy and conscious attempts to manage even a complex technology, rather than relegate design or development activities to less disciplined job-shop approaches.

International Management. Increased communications and global operations have brought the issues of the multinational corporation and international management into high prominence. The Sloan School, as is true of the rest of MIT, has always attracted substantial numbers of non-US students and its faculty have consistently maintained communication with many other countries. The faculty in international management play a leadership role in many of these activities.
Professor Donald R. Lessard has been engaged in research on country risk and the structure of financial intermediation in developing countries. He has found that the structure of their external obligations to be a major contributing factor to the current debt crisis and has been seeking an understanding of factors that may have led to alternative patterns of finance. In other work he has studied the measurement and management of international exposure to exchange rate fluctuations with a particular emphasis on the linkage between finance and operations.

The Pacific rim is a special focus of the international management group, especially Professor D. Eleanor Westney, a Japan scholar, and Professor Denis F. Simon, a China specialist. Professor Westney has been doing a comparative analysis of the careers and the organization of engineers in R&D in the computer industry in three Japanese and three US firms. She is also engaged in field research on an environmental scanning project that is part of the Management in the Nineties program. Professor Simon has been doing research on technology transfer and the assimilation of technology into developing countries. A current study concerns the modernization of Shanghai's electronics industry. His research analyzes how changes in China's economic climate affect the behavior of firms regarding technological innovation and foreign technology acquisition.

Health Care Management. The efficient and effective delivery of health care is a major economic and social issue. The Sloan School, through the research of its faculty and their involvement in the Division of Health Policy and Management of the Whitaker College, continues to play an active role. Senior Lecturer Stan N. Finkelstein, who directs the Interdisciplinary Laboratory for Health Care Studies in Whitaker, is doing research on a variety of topics, including a cross-state comparison of solid organ transplant policies in which the goal is to classify different approaches and relate them to such issues as the relation between clinical experience and success rates. A continuing interest concerns insurance coverage decisions for emerging medical technologies. He seeks to understand the nature of the information that is sought and used for the coverage decision and to measure its potential to change the practice behavior of physicians. In work that spans the technology and health areas, Professor Roberts, as mentioned earlier, has been studying the formation of biomedical firms, including consideration of their linkages to medical schools and hospitals and the impact of federal regulations.

Law. Professor J. D. Nyhart has made a persuasive case that law, traditionally only a teaching area at the Sloan School, should also be a subject for research. He has identified several promising directions for a research effort. One of these is alternate methods of dispute resolution. He has been particularly active in conflict resolution over issues arising in use of the oceans, the coastal zone, and the continental shelf. He is now involved in an extensive new project in computer-assisted negotiation. Professor Judith A. Lachman is also interested in issues of negotiation and conflict management and she has a further research effort on issues of liability in the provision of health care, products, and other services.

Communications. Senior Lecturer JoAnne Yates has been researching and writing a scholarly book on internal communications within American firms during the period 1850-1920 and now has completed a full draft. She has further collaborated with Professor Malone and Visiting Researcher Robert Benjamin on the effects of contemporary information technology on firms and markets.

It is a pleasure to report that two of Dr. Yates's articles won awards in 1986. Her article on "Graphs as a Managerial Tool: A Case Study of Du Pont's Use of Graphs in the Early Twentieth Century" won the Alpha Kappa Psi Award for Distinguished Publication in Business Communication, and "Internal Communication Systems in American Business Structures: A Framework to Aid Appraisal" won the Ernst Posner Prize for the outstanding contribution of the past year to archival literature.

Significant awards went to two other faculty members as well. Professor Venkatraman's doctoral thesis received the A. T. Kearney Award for outstanding research in general management by the Academy of Management for the best doctoral dissertation completed in 1985. Professor Allen has been honored with the "Paper of the Year Award" by R&D Management for his paper with Professor Ralph Katz of Northeastern, "The Dual Ladder: Motivational Solution or Managerial Delusion?"

AFFIRMATIVE ACTION

During the past year, the School appointed 27 individuals after conducting a serious affirmative action search in each of these instances. We appointed 12 new faculty, including three women and one Asian American; there were also 12 new staff appointments, including five women and one Hispanic male; and there were three new research staff appointments, including two women.

Our continuing affirmative action efforts have yielded a significant increase in the number of women across all ranks as well as the addition of some minorities. We have continued to make strong efforts to attract more minorities to our open slots and can demonstrate the impact of this effort with the following data. Across our faculty search efforts, 11 of the 39 finalists for these positions were minorities (two Hispanic Americans and nine Asian Americans); across the staff searches, there were five Asian Americans, three black Americans, and one Hispanic American. In our research staff searches,
there were five black American finalists. Although a small number of these candidates were offered appointments at the School, the data demonstrate that we are making some progress in attracting minorities to our openings and that our strategy should serve as a foundation for future progress.

There are two essential components to our affirmative action strategy to increase the number of under-represented minorities and women in our ranks: (1) we seek to increase the pool of qualified candidates through participation in our degree programs, and (2) we seek to increase the pool of qualified candidates who apply for our open positions.

In order to increase the pool of qualified minority candidates, we offer a number of fellowships at the Sloan School: The Exxon Foundation has given the Sloan School approximately $8,500 each year to support minority fellowships for students in our master's program. Allied Chemical Corporation provides approximately $4,000 per year to the School to support a fellowship to a minority or female student in our master's or doctoral program. COGME (Council for Opportunity in Graduate Management Education) provides approximately $25,000 each year to support a fellowship for minority students in our master's program. Dresser Industries, American Express, and other organizations have provided the School with gifts to support fellowships for minority graduate students.

The Phyllis A. Wallace Doctoral Fellows Fund has been established to provide support for a black person (or persons) admitted to the Sloan School doctoral program. The goal of this fund is $350,000. In addition, we have also established a Phyllis A. Wallace Visiting Scholars Fund to provide support for a black Visiting Scholar at the School. The goal of this fund is $650,000. Income from these funds will be made available to support appropriate candidates.

In addition to the special efforts in our degree programs, we have developed guidelines as part of our serious search process to ensure that women and minorities are sought when a position becomes open.

When a faculty search plan is submitted, the Dean's Office reviews the plan to ensure that efforts will be made by the relevant area (in addition to the general School efforts) to attract women and minorities. Part of these additional efforts specifically require a plan for a number of planned interviews to be conducted with women and minority candidates.

In both faculty and staff searches, we rely on personal contacts of our faculty and staff to reach individuals in leading business schools who will help us identify qualified women and minorities for our positions. We have also asked our faculty and staff women and minorities to help us establish networks and personal linkages with qualified candidates. We continue to develop more formal contacts with individuals in agencies or organizations known for their efforts in the identification and placement of women and minorities. Over time, we hope that all of these efforts will yield an increasing number of qualified candidates for our positions.

**EXTERNAL RELATIONS**

The School continues to strengthen its relationship with its external constituencies, creating long-term bonds with our alumni/ae, with foundations, and with corporations interested in supporting our goals and the initiatives we plan to undertake.

We are very honored by two generous gifts made this year to support two new professorships at the School. Nomura Securities Co., Ltd. of Tokyo, Japan, contributed $1.5 million to the School to support a professorship in the area of finance. We were pleased to announce Professor John C. Cox as the first chairholder, a brilliant scholar who we believe will bring distinction to the chair. Our second newly established chair this year was made possible through a gift of $750,000 from Patrick J. McGovern ('59), with additional gifts totaling $750,000 to be made over the next five years. The purpose of this gift is to provide for a full professorship in the area of management information systems and related areas in the Sloan School. The School is in the process of selecting the first member of our faculty to be appointed to this chair.

A number of other resource development efforts worth noting include: a $200,000 grant from Cigna Corporation to support "Management Theory and Advanced Information Technology" through the Management in the Nineties program; $43,000 in gifts from SSM alumni and friends to support an endowed fund for Sloan Research and Curriculum Development; $43,000 in contributions directed toward the Miriam Sherburne Fund to fund a scholarship and support of other student-associated needs of the master's program; a $40,000 unrestricted gift from General Motors, concluding a five-year commitment of unrestricted funding from the foundation; $15,000 from the Little Family Foundation to support fellowships for master's candidates; and $19,000 from the Sloan Foundation to support a conference in "New Developments in Labor Markets and Human Resource Policies."

Our resource development efforts this year have yielded, overall, a total of over $3.6 million in financial support to the School and for this we are most appreciative. We will continue to move forward to improve the relations that are vital to the School and to the Institute.
The alumni/ae relations program was revised and strengthened over the course of the past year. It was felt that the alumni/ae would be best served by those who had an active involvement with and understanding of the current student programs. With this in mind, Jeffrey A. Barks, Associate Dean for Master's and Bachelor's Programs, was asked to assume responsibility for the alumni/ae of the master's, bachelor's, and doctoral programs, while Alan F. White, Associate Dean for Executive Education, continued with his responsibility for alumni/ae relations involving former participants in all executive education programs. In this way the alumni/ae find themselves in frequent contact with many of the people they knew as students, and relationships built during student days can continue to grow, leading directly to a more active alumni/ae body.

The Sloan Club, a national organization representing Sloan School master's and doctoral program graduates, continued this year to present a wide variety of programs to Sloan alumni/ae through the efforts of several existing regional chapters. Interest has arisen in founding new chapters in areas where the Sloan alumni/ae population continues to grow, with requests for support coming from San Diego and Florida. Sloan Club activities are open to alumni/ae from all Sloan programs, and events sponsored jointly with local MIT clubs are quite frequent. The Sloan Club of Washington, for example, co-sponsored an event with the MIT Club, hosting former Sloan Dean William F. Pounds. The national board of the Sloan Club meets at Sloan three times during the year to review the progress of its activities, share ideas and support among regional chapters, and discuss ways to better serve both the alumni/ae and the School.

Functions sponsored by the School for its alumni/ae included, among others, a reunion for the fifth, 10th, and 25th year classes, held in June, one high point of which was a dinner dance held at the MIT Faculty Club. The annual Summer Gatherings also continued to be popular events. In the summer of 1986 these social occasions for alumni/ae and current students were held in Boston, New York, and San Francisco; the summer of 1987 will see this tradition continue and expand as a gathering is planned for Washington as well.

The Board of the Society of Sloan Fellows elected new officers this year. The new President is Robert Campbell, President of The Sun Company (Sloan Fellow '78). The new Vice President is Richard Santagati, Chief Operating Officer at Gaston Snow & Ely Bartlett (Sloan Fellow '79), and the incoming Secretary-Treasurer is Ronald Turner, Vice President at Martin Marietta (Sloan Fellow '77). The retiring President, Wendell Cook of Eastman Kodak (Sloan Fellow '68), gave many years of service in support of the Sloan Fellows Program.

The triennial Convocation for the alumni/ae of the Sloan Fellows Program was held during 1986. Over 800 attended the event, which had the theme "Management in the Nineties."

SLOAN, the School's alumni/ae magazine, is published twice each year. This year's winter edition featured Ken Estridge, SM '68 and founder of Joy of Movement Center. The spring edition cover article was devoted to Dean-designate Lester C. Thurow.

The new plan of action for Sloan's alumni/ae relations promises an expanded and more active commitment on the part of the School to strengthening the connection between the Sloan School and its alumni/ae body.

STAFF CHANGES, PROMOTIONS, AND VISITORS

During the 1986-87 academic year, two faculty members were named to two new professorships at the School. John C. Cox was named Nomura Professor of Finance, a new chair established through the generous gift of the Nomura Securities Co., Ltd. of Tokyo, Japan. Professor Cox has been working in two areas—in the development and application of equilibrium models which integrate real and financial variables, and in the area of contingent claim valuation theory. Professor Cox has been on the Sloan School faculty since 1983.

Robert M. Freund was named to the Elisha Gray II Career Development Chair, an Institute chair established through the generous donation of Mr. Elisha Gray to support the activities of a promising assistant professor. Professor Freund joined the School faculty in 1983 as Assistant Professor of Management Science. His teaching and research interests are in the area of mathematical programming, including complementary theory, fixed points, and nonlinear programming.

Eric A. von Hippel was promoted to the rank of Professor. Professor von Hippel received a PhD in Management from Carnegie-Mellon University in 1974. He joined the Sloan School faculty in 1973 in the innovation group. Professor von Hippel is widely acknowledged to have made fundamental contributions to the understanding of innovative activities in US industry, focusing on the functional laws of innovation and the mechanisms whereby the benefits of innovation are appropriated.
Three Associate Professors were granted tenure this year. James B. Orlin received a PhD in 1981 from Stanford University. He came to the School in 1979 in the operations research group and has made significant contributions in his teaching and research in the areas of combinatorial and network optimization and mathematical programming.

Julio J. Rotemberg received a PhD in Economics from Princeton University in 1981. He joined the applied economics faculty at the School in 1980 and has focused his teaching and research in the fields of macro and international economics. In particular, his accomplishments have been concentrated in the study of the relationship between business decisions and macro-economic fluctuations.

Thomas M. Stoker joined the applied economics faculty in 1979, after receiving a PhD in Economics from Harvard University. Professor Stoker's research has focused on aggregation problems-issues, theoretical and empirical, that arise when micro-relations pertaining to the economic behavior of individual units are transformed into relations for a group or population as a whole.

Two faculty were promoted to the rank of Associate Professor. John Sterman was appointed Assistant Professor in the system dynamics group in 1981 and received a PhD in 1982 from MIT. His research has been involved with energy modeling, specifically developing a general disequilibrium approach to macro-economic modeling, and with the development of an integrated theory of long economic cycles.

D. Eleanor Westney received a PhD in 1978 from Princeton University before joining the international management faculty. In 1982, she was appointed to the Mitsubishi Career Development Chair. Professor Westney's expertise is in Japanese studies; her major work has been a historical study of organizational development in Japan during the Meiji period.

Eight new Assistant Professors joined the School this year. Deborah L. Gladstein Ancona, Assistant Professor of Organization Studies, received a PhD in Business Administration from Columbia University in 1982. Ravi Bhushan, Assistant Professor of Accounting, received a PhD from the Graduate School of Business at the University of Chicago in 1986. Michael A. Cusumano, Assistant Professor in the strategy group, received a PhD from Harvard University in 1984. Kenneth A. Froot, Assistant Professor of Economics, received a PhD in Economics in 1987 from the University of California at Berkeley. Frank Kardes, Assistant Professor in the marketing group, received a PhD in Psychology from Indiana University in 1986. Don N. Kleinmuntz, Assistant Professor of Organization Studies, received a PhD in Behavioral Science and Statistics from the University of Chicago in 1982. Judith A. Lachman, Assistant Professor of Law, received a JD from Yale Law School in 1982. Robert J. Thomas, Assistant Professor of Organizational Behavior, received a PhD in Sociology from Northwestern University in 1981.

The School also welcomed a number of visiting faculty this year. There were six Visiting Professors. Frank Fabozzi, from Lafayette College, taught Management Accounting and Control and Financial and Cost Accounting in the fall. Donald W. Hearn, from the University of Florida, taught Decision Support Systems and Non-linear Programming and Discrete Time Optional Control in the spring. Robert J. House, from the University of Toronto, taught Managerial Behavior in Organizations in the fall. Scott F. Richard, from Carnegie-Mellon University, taught Finance Theory in the fall. Howard Thomas, from the University of Illinois, taught Research Seminar in Corporate Strategy and a Special Seminar in Management-Strategic Models in the spring. Stavros B. Thomadakis, from Baruch College, City University of New York, taught Accounting and Finance and topics on Corporate Financial Management in the spring.

Four Associate Professors visited the School this past fall and spring. Paul Osterman, from Boston University, taught Management of Human Resources and a related thesis seminar this spring. Thomas A. Poynter, from the University of Western Ontario, taught International Dimensions of Management and Strategy in a Global Context during the spring term. Michael J. Marcus, from Bell Telephone Laboratories, taught Telecommunications Technology and Policy in the fall. Russell S. Winer, Visiting Associate Professor of Marketing from Vanderbilt University, taught Introduction to Marketing Management this spring.

Six Assistant Professors visited the School, including Ravindra K. Ahuja, from the Indian Institute of Technology, co-taught Combinatorial Optimization in the fall and taught Network Optimization in the spring. Susan deTreville, from the Helsinki School of Economics, taught Introduction to Operations Management and Manufacturing Policy in the spring. Peter J. Kemphorne, from Harvard University, worked with the faculty in the area of statistics. Charles D. Kolstad, from the University of Illinois, taught Energy Economics and Policy in the fall. Bert Spector, from Northeastern University, taught Industrial Relations and Human Resource Management in the spring. Richard Wang, from the University of Arizona, taught Expert Systems in the spring.

Senior Lecturers, Lecturers, and Instructors appointed at the School included: Peter P. Gill, previously Associate Dean at the School, lectured in the Executive Education Program; John S. Hammond taught Strategic Management in the fall; Rita Vachani taught Introduction to Management Science; N. Sandra Nickel taught Communication for Managers; and Gloria Schuck taught Managing the Developmental Effort.

The School also brought on board Subhash Bhalla, Visiting Scientist, to work with Professor Stuart E. Madnick; and Chandler H. Stevens, Visiting Fellow, who worked in the Management in the Nineties program.
A number of faculty spent all or part of the year on sabbatical leave. Arnoldo C. Hax, Alfred P. Sloan Professor of Management; Jeremy F. Shapiro, Professor of Operations Research and Management; and Thomas M. Stoker, Associate Professor of Applied Economics, were on leave the full year. John R. Hauser, Professor of Management Science, was on leave for the spring, and Glen L. Urban, Professor of Management Science, was on leave for the fall.

Faculty on professional leave included Lotte Bailyn, Professor of Organizational Psychology and Management, and M. Anthony Wong, Associate Professor of Management Science, on leave for the year; D. Eleanor Westney, Mitsubishi Career Development Associate Professor of International Management, and John E. Parsons, Assistant Professor of Finance, on leave for the spring; and Sudhir Krishnamurthi, Assistant Professor of Management, on personal leave.

Still on leave were Katharine G. Abraham, Associate Professor of Industrial Relations, and John J. Donovan, Associate Professor of Management Science.

Returning from leave were Donald R. Lessard, Professor of International Management; Robert S. Pindyck, Professor of Applied Economics; Richard S. Schmalensee, Professor of Management and Economics; Edgar H. Schein, Sloan Fellows Professor of Management; and Eric A. von Hippel, Professor of Management.

Staff promotions during the past year included Donna M. Behmer, who was promoted from Director of Finance and Administration to Assistant Dean for Administration; Leo F. Brilody, who was promoted from Programmer Analyst to Systems Programmer III; Norma Gicka, who was promoted from Administrative Assistant to Fiscal Manager; Carol A. Peterson, who was promoted from support staff to Circulation Manager of Sloan Management Review; and Jennifer A. Mapes, who was promoted from support staff to Coordinator of The MIT Management of Technology Program.

Two staff transferred to the School—Hillary De Baun, who transferred from the Electrical Engineering Department to become Undergraduate Program Coordinator, and Judith A. Stein, who came as Administrative Assistant from the Earth and Planetary Science Department.

Four administrative staff joined the School: Neil G. Buckley, Jr., Administrative Coordinator; Charles R. Grader, Associate Director of Executive Education and Director of the Program for Senior Executives; Mario L. Gnecco, Program Director for The MIT Management of Technology Program; and David A. Weber, Associate Director of the Master's Program and Director of Student Services.

There were two promotions within the Research Staff: Connie Perin was promoted to Principal Research Associate from Research Associate, and Elizabeth Sears Parsons was promoted to Sponsored Research Staff Administrator from support staff. We also welcomed James A. Hernon as a Research Specialist for the Management in the Nineties program and James Short as Research Associate in the Center for Information Systems Research.

Three faculty and one staff member retired this year: Sidney S. Alexander, Professor of Management and Economics; Louis L. Banks, Adjunct Professor; Gordon Bloom, Senior Lecturer; and Esther Merrill, Undergraduate Program Coordinator.

A number of individuals departed from the School, including Associate Professor Richard S. Ruback; Assistant Professors Sudhir Krishnamurthi and Denis F. Simon; Senior Lecturers, John S. Hammond and Harlan C. Meal; Lecturer, Charles M. Jonscher; Instructors, Marc Meyer and Rita Vachani; Administrative Staff, Margaret Gutowski, Laura Mersky, Jane Morse, Julius Niewiarowski, and Jacalyn Walker-Sharp; and Research Staff, Mary Anne Brady, Kenneth R. Grant, Mark D. Hunsberger, Bandreddi E. Prasad, and Ellen S. Quackenbush. We value the contributions made by each of the individuals mentioned during their stay at the School.

It is with great sadness that we mention the death of a valued member of the Sloan faculty, Zenon S. Zannetos, Professor of Management and Senior Associate Dean for Development. During the more than 30 years of service to the School, Professor Zannetos contributed extensively to the development and teaching of the Executive Education Program and to research in the areas of planning and control systems, accounting systems, the design of organization structures, intelligent information systems, productivity and innovation, and the impact of technology on education. Professor Zannetos also served in an important administrative role as Senior Associate Dean for Development. We remember Professor Zannetos not only for his significant contributions but as a long-standing personal friend who will be missed by all of us.
One of the important developments in the past year in the School of Science has been the decision to proceed with the establishment of a new science complex. The plan is to build a new biology building on a portion of the "TRW property" that MIT has recently acquired. This property is on Vassar Street directly across from the Seeley-Mudd Building which houses the Center for Cancer Research. Upon completion of the new building, the members of the Biology Department currently housed in the Dorrance Building (Building 16) and the Whitaker Building (Building 56) will be moved into the new building and, after some necessary but relatively minor renovations in the Whitaker Building, those faculty members in the Department of Applied Biological Sciences currently in the Dorrance Building will move to the Whitaker Building. These moves will allow the Dorrance Building to be vacated for much-needed and extensive renovations that cannot be undertaken while the building is occupied. These renovations will be designed to allow a portion of the Physics Department to be relocated in the Dorrance Building, thereby liberating space that will be available for reassignment for other purposes. These plans offer the attractions of: (a) providing modern facilities for the biologists in a central location with respect to other buildings that are occupied by biologists; (b) allowing the Department of Applied Biological Sciences to be consolidated in appropriately modified quarters in the Whitaker Building (Building 56); (c) providing newly renovated space for some of the physicists in the Dorrance Building (Building 16), located adjacent to Buildings 6 and 26, both of which will continue to be occupied by other members of the Physics Department; and (d) making available for reassignment space approximately equivalent to the amount of net assignable space in the new biology building.

Implementation of these plans will, indeed, create a group that can be referred to as the Science Complex since the Dreyfus Building (Building 18), occupied by the Chemistry Department; the Dorrance and Whitaker Buildings; the new biology building; the Seeley-Mudd Building, occupied by the Center for Cancer Research; the Whitehead Institute; the Green Building, occupied by the Department of Earth, Atmospheric, and Planetary Sciences; the Whitaker College building; and Building 26 (containing physicists who are members of the Laboratory for Nuclear Science) are all located in the same general area. Another advantage is that the Landau Building (Building 66), which provides quarters for the Chemical Engineering Department, is located in close proximity. This is important because many members of that department interact regularly with faculty in the Chemistry, Biology, and Applied Biological Sciences Departments. One of the high priority fund-raising initiatives in the next few months is to provide resources to allow implementation of these plans.

EDUCATION

The School of Science education committee, chaired by Professor Robert Silbey, has submitted its report. The principal recommendation from this committee is that the Science Distribution Requirement should be modified to: (a) reduce the number of subjects that can be used to satisfy this requirement; and (b) provide oversight by a committee and the Dean of Science to insure that the subjects on the list are appropriate to satisfy the stated intent of the requirement. The committee also strongly recommended that each undergraduate at MIT should have laboratory experience in which the student is responsible for "gathering and analyzing data on some real research problem and drawing conclusions from these data". The committee made no recommendation about how this should be implemented because the members believe that this is an Institute-wide issue and, therefore, implementation should be addressed by a more broadly-based committee.

An innovative and experimental educational project, undertaken with the cooperation and participation of the office of the Dean of Undergraduate Education, was begun in the past year and will be continued and expanded in the coming year. This is the so-called "linkage" of certain recitation sections for 8.01 and 18.01, two of the important "science core" subjects taken by undergraduates in the first year. This program is designed to "link" mathematics and physics for students in these sections and, thus, to illustrate the relatedness of these two subjects. One of the positive features of this program is the necessity for the physics and mathematics instructors to meet regularly and discuss one subject in the context of the other and decide how best to present the material to their students. This is an experimental program which will be expanded if the experiment is as successful as it promises to be.

AFFIRMATIVE ACTION

There were several appointments of females and underrepresented minorities in the school during the year. Dr. Iris Mack was appointed as Visiting Assistant Professor in the past year and has been reappointed for the 1987-88 academic year. Dr. Cato Laurencin has been appointed as Instructor in the Department of Applied Biological Sciences for the coming year. The Chemistry Department has recently appointed Dr. Joanne Stubbe as Professor. She will arrive in September, 1987. Dr. Stubbe will be the first tenured
woman faculty member in the history of the department. Dr. Terry Orr-Weaver and Dr. Ruth Lehmann have been appointed as Assistant Professors in the Biology Department with joint appointments in the Whitehead Institute. The Physics Department appointed Dr. Susan Cooper as Assistant Professor this past year. Promotions to tenure were granted to Professors Marcia McNutt and Paola Rizzoli of the Department of Earth, Atmospheric, and Planetary Sciences.

In addition, offers were made for faculty positions to a female (EAPS) and to an underrepresented minority (Biology); both declined the offers.

The School of Science has joined with Dean John Turner, Associate Dean of the Graduate School, to organize and sponsor the MIT Minority Summer Science Program. This program allows minority undergraduate students, usually third year students, to spend the summer at MIT working in the research laboratories of faculty members in the School of Science. Applications are solicited nationwide and the most promising applicants are selected and placed in research laboratories that match the interests of the students. This program was initiated in the summer of 1986. Eight students were selected for the first year and by all criteria it was a very successful operation. The program was continued for the summer of 1987 with the participation of 12 students. From testimonials by students, it is clear that by introducing these students to MIT's brand of scientific research this program has been important in helping them to decide whether or not to attend graduate school. Most of them have said that they are more likely to apply to graduate school because of their positive experiences in this program. We plan to continue and expand the program in future years. We hope to have 24 students here for the summer of 1988. I want to express my thanks to everyone who has helped to establish this important program: department heads, faculty members, post-doctoral fellows, graduate students, the Provost (who made support funds available), and especially to Dean Turner who provided the leadership to make this program possible.

STAFF CHANGES

It is a pleasure to report that during the 1986-87 academic year Evelyn Perez and Charlene Placido were promoted to Assistant Deans in the School of Science. Evelyn's responsibilities are in the personnel area and Charlene handles the financial affairs of the School.

In October, 1986, Ms. Judith Gooch was appointed as Development Officer for the School of Science. She reports jointly to the Dean of Science and to the Vice President for Development. As we begin the Institute-wide fund-raising campaign it is particularly important to have a person on board whose responsibility is to help plan and implement fund-raising activities for the School of Science. Judith comes to us with a lot of experience in development and she has immediately and effectively laid the groundwork for a comprehensive development program for the School.

After having served for five years as Head of the Chemistry Department, Professor Christopher Walsh gave up this post as of June 30, 1987, and has accepted the position of Chairman of the Department of Biological Chemistry and Molecular Pharmacology at Harvard Medical School. It was a real pleasure to have had Professor Walsh as a colleague on the Science Council. He carried out his responsibilities as department head with competence and a style that has set the standard for department heads in the School. I am sorry that MIT has lost his services, but we send him to Harvard with our best wishes.

Professor Mark Wrighton will replace Professor Walsh as Head of the Chemistry Department. Professor Wrighton is a distinguished inorganic chemist and I welcome him to the Science Council with enthusiasm.

ACADEMIC PROGRAMS

There were 770 undergraduates in the School of Science during the past academic year, a 4.9% decrease from the previous year. The number of minority students at the undergraduate level changed as follows:

<table>
<thead>
<tr>
<th>Minority Group</th>
<th>Change</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blacks</td>
<td>decreased from 21 to 14</td>
<td>-33%</td>
</tr>
<tr>
<td>Hispanics</td>
<td>decreased from 23 to 19</td>
<td>-17%</td>
</tr>
<tr>
<td>Native Americans</td>
<td>decreased from 2 to 1</td>
<td>-50%</td>
</tr>
<tr>
<td>Asian Americans</td>
<td>increased from 107 to 121</td>
<td>+13%</td>
</tr>
</tbody>
</table>

The female undergraduate population decreased by 4.7%. Twenty-two percent of the Institute's upperclass undergraduates were enrolled in the School of Science.
Graduate enrollments in science decreased from 1,123 in the 1985-1986 academic year to 1,115 in the 1986-1987 academic year. The total enrollment represents 21 percent of the graduate population at MIT. The number of minority students at the graduate level changed as follows:

- Blacks: increased from 17 to 19 (11.7%)
- Hispanics: increased from 4 to 8 (+100%)
- Native Americans: no change
- Asian Americans: increased from 4 to 5 (25%)

The number of female graduate students decreased by 4.7 percent.

There were 274 faculty members in the School this past year. This represents a slight decrease from the previous year. The undergraduate student-to-faculty ratio was 3 to 1, and the graduate student-to-faculty ratio was 4 to 1.

RESEARCH

The FY'87 volume of the School of Science was approximately $89 million. This represents a 4.7 percent increase over the FY'86 corrected total of $85 million.

FACULTY

Many honors and awards were accorded to faculty in the school this year as reported in the individual departmental reports and in the following paragraphs. In the Department of Applied Biological Sciences: Professor Marcus Karel was named the recipient of the Nicholas Appert Award of the Institute of Food Technologists, which honors "pre-eminence in and contributions to the field of food technology;" the 3M Foundation honored Professor Chokyun Rha for her work on the hydrodynamic properties of chitosan. Professor Alexander Klibanov was named the 1986 winner of the Leo Friend Award in Chemical Technology. The award is given annually to the author of the best paper published in the American Chemical Society's Journal of Chemtech. The 1986 Food, Pharmaceutical, and Bioengineering Award was presented to Professor Robert Langer by the American Institute of Chemical Engineers. Professor Langer is the youngest recipient of this award. Several faculty members in the Department of Biology were recognized for their contributions to science, among them: Professor Phillip Sharp, Director of the Center for Cancer Research, was named recipient of the Alfred P. Sloan Prize, one of three annual prizes given by the General Motors Cancer Research Foundation. Professor Steven Burden was named as the first holder of the Thomas D. and Virginia W. Cabot Career Development Professorship, which was established to recognize excellence in teaching and research by young faculty members of exceptional promise. Professor David Raulet was also named the first holder of a chair, The Robert A. Swanson Assistant Professorship in the Life Sciences, in recognition of his work in immunology. In the Department of Chemistry, Professor John Waugh received the Distinguished Alumni Award, the highest honor given by his alma mater, the California Institute of Technology.

The Joint Policy Board for Mathematics awarded its first Public Service Award to Professor Kenneth Hoffman of the Department of Mathematics for his work in developing a "national mathematics science policy." Also in the Department of Mathematics, Professor Richard Melrose was elected to the American Academy of Arts and Sciences.

Promotions to Associate Professor were granted to Professor Sylvia Ceyer and Keith Nelson of the Chemistry Department.

A two-day symposium, "The World of Philip Morrison", was held in September to celebrate the contributions of Professor Morrison by a group of his colleagues. One of the most renowned physicists worldwide, Professor Morrison was also the first winner of the Andrew Gemant Award established by the American Institute of Physics.

GENE M. BROWN
The programs of the Department of Applied Biological Sciences continue to evolve, reflecting the redefinition of the objectives and composition of its faculty and student body. The graduate degree programs have been fully consolidated, and at the June commencement all doctorate degrees of graduates were awarded in Applied Biological Sciences for the first time. A continuing search has been in operation to identify new faculty members to replace those who have resigned or retired, and we expect to fill currently open positions during the coming academic year. One new member, Dr. Helmut Zarbl, has been appointed, and applicants are being evaluated for the remaining positions.

A symposium jointly sponsored by the Department and the Industrial Liaison Program entitled "New Initiatives in Applied Biological Sciences" was held in March, 1987, to signify the changes in the departmental name and in its programs. The program included presentations by leading experts in various areas of applied biology, including members of the departmental faculty, and was very well attended by representatives of industry as well as the academic community.

**FACULTY**

The past year has been one of significant change with respect to the status of several members of the departmental faculty. Dr. John M. Essigmann, Associate Professor of Toxicology, was awarded tenure, and Dr. Marsha R. Rosner, Assistant Professor of Toxicology, was promoted to Associate Professor, both promotions will be effective as of July 1, 1987.

Dr. Michael A. Marletta, Associate Professor of Toxicology, accepted an appointment as Associate Professor in the Department of Medicinal Chemistry of the University of Michigan, a position which he will assume July 1, 1987.

Dr. George Wolf, Professor Emeritus and Senior Lecturer, will formally retire as of July 1, 1987, but will continue to serve for an additional year as Chairman of the Committee on the Use of Humans as Experimental Subjects.

Dr. Helmut Zarbl was appointed as Assistant Professor and will join the faculty on July 1, 1987. Dr. Zarbl received his doctorate in biochemistry from McGill University, Montreal, followed by postdoctoral experience at the National Cancer Institute of the NIH, and the Clinical Research Institute of Montreal. His research interests are in the area of cellular growth regulation, and in particular, genetic alterations responsible for malignant transformation. His previous research included characterization of mechanisms of oncogene activation by chemical carcinogens, an area he will continue to explore in the context of his longer term interests.

Dr. Cato T. Laurencin has been appointed Instructor in Biochemical Engineering, also effective July 1, 1987. Dr. Laurencin received his undergraduate education in chemical engineering at Princeton University and thereafter enrolled in the Harvard-MIT combined MD-PhD program. He received both degrees at the June commencement and will serve as Instructor on a part-time basis while completing a residency in orthopedics at the Massachusetts General Hospital. He will participate in teaching as well as research activities.

**RESEARCH PROGRAMS**

The research programs of the departmental faculty and their colleagues have continued to flourish during the past year, as indicated by the continued increase in research funding received from federal and other sources. The major areas of research activity continue to be in applied biochemistry, biotechnology, biochemical engineering, microbiology/genetics, and toxicology. Further information about the specific research programs of each faculty member is available in the Faculty Research Summaries, which are available in the Department headquarters, Room 16-333.

**EDUCATIONAL PROGRAMS**

During this academic year, undergraduate majors enrolled in the Applied Biology program (Course VIIB) numbered 36 during the Fall term, and 35 in the Spring term. In addition, there was strong participation of faculty and staff in UROP projects for undergraduates. In all, a total of 16 faculty members supervised research projects for an average of 28 students during each of the academic terms. Other interactions with undergraduates included participation as freshman advisors and premedical advisors.

As the research emphasis as well as the composition of the faculty has continued to change over the past years, extensive revisions have also been made in the curriculum for graduate study leading to degrees in the Department. The consolidation of specialized degree programs into a single departmental degree program has been completed and, as of the entering class of the Fall, 1986, term, all graduate students entering the Department will receive degrees in either Applied Biological Sciences or in Biochemical Engineering. The latter program has been in existence for many years and is successfully offered jointly with the Departments of Chemical Engineering and Biology. Fields of specialization currently offered within the Applied Biological Sciences program include biotechnology, biochemical engineering, and toxicology.

The number of graduate students enrolled as SM or PhD candidates in the Department numbered 102 during the Fall term and 89 during the Spring term. Doctoral degrees were awarded to 25 students and SM degrees to three students.
HONORS AND AWARDS

Honors and awards were accorded to several members of the faculty of the Department during the past year.

Renee A. Fitts, Assistant Professor of Applied Biological Sciences, was awarded a Henry L. Doherty Professorship in Ocean Utilization, which helps to support her work in the biological monitoring of aquatic environments.

The Leo Friend Award in Chemical Technology was awarded to Alexander M. Klibanov, Professor of Applied Biological Sciences, by the American Chemical Society.

Vernon R. Young, Professor of Nutritional Biochemistry, was the recipient of the McCollum Award of the American Society of Clinical Nutrition.

Douglas C. Youvan, Assistant Professor of Applied Biological Sciences, was awarded an ARCO professorship to pursue research in establishing data and instrumentation for remote definition of patterns of distribution of marine organisms.

A number of students in the Department of Applied Biological Sciences were honored with awards during the 1986-87 academic year. Cato Laurencin was, for the third consecutive year, the recipient of the prestigious Hugh Hampton Young Memorial Trust Fund Scholarship. Mr. Laurencin’s thesis research, conducted in the laboratory of Robert S. Langer, Professor of Biochemical Engineering, is entitled "Novel Bioerodible Polymers for Controlled Release Analyses of In Vitro/In Vivo Performance and Characterizations of Mechanism."

Kim Ellison, a graduate student in Professor John Essigmann’s laboratory, was selected to receive the Swanson Fellowship, an award which provides tuition and a stipend. The Fellowship is made possible through the generosity of Mr. Robert Swanson, President of Genentech, Inc., in San Francisco. Ms. Ellison’s research focuses on chemical and biochemical mechanisms underlying mutation and cancer.

Claus von der Osten was awarded a Whitaker Health Sciences Fund Fellowship for 1986-87. Mr. von der Osten works in the laboratory group of Anthony J. Sinskey, Professor of Applied Microbiology, on the relationships between the structure and properties of yeast cell wall polysaccharides.

The Department presented the first M. M. Znaty Award for Graduate Research to Nazneen Aziz. The award was established in memory of the late Miriam M. Znaty by her parents and friends to carry forward her deep interest in scientific achievement and enthusiasm for the research to which she committed her own efforts. Ms. Aziz received a prize of $500 and financial support to present her research findings at a meeting of a professional society. Ms. Aziz’s research for her thesis, entitled "Regulation of Ferritin Gene Expression by Iron," is being conducted in the laboratory of Hamish N. Munro, Adjunct Professor of Physiological Chemistry.

Two students tied for first place in this year's Bernard E. Proctor Undergraduate Research Award Competition. They were Cindy Wang, '89, who worked on salmonella research in Professor Renee Fitts' laboratory, and Timothy Lash, '87, who conducted research on poliovirus under the direction of Marie B. Chow, Assistant Professor of Applied Biological Sciences. Both students will have an opportunity to present their research findings at a scientific conference, with all expenses paid.

GERALD N. WOGAN
INTRODUCTION

The Biology Department continues to prosper with its established productive faculty members and with new appointments. The Department continues to be one of the most highly regarded biology departments in the country. The commitment by the MIT administration to construct a new building for the Department as part of the Science Complex is a very welcome realization of the needs for rejuvenation of aging facilities and for modern research space for those department members still based in the old buildings. This commitment will help ensure the continued strength of the Department.

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Life Sciences majors was 284. Of these, 78 received the degree of Bachelor of Sciences in Life Sciences: 56 in the regular Course VII program, 17 in the VII-A Program, and five in the VII-B Program. Most of these graduates will attend either medical or graduate school.

The recipient of the John L. Asinari Award for outstanding research by undergraduates in Life Sciences for 1986-1987 was Antoine A. Firmenich, a junior, working in the Laboratory of Professor Herman N. Eisen in the Department of Biology. Honorable mention went to Jeff Himawan, a senior, working in the laboratory of Professor Graham C. Walker, also in the Department of Biology.

This spring we removed 7.01 General Biology as a requirement in the Biology curriculum and revised the format of the subject to bring it up to date with recent developments in molecular biology and keep the focus on current research.

Graduate Program

During the period from July 1, 1986 to June 30, 1987, 17 Ph.D. degrees and one Master's degree were awarded in the Department; one Ph.D. and one Master's degree were awarded in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute (WHOI). The maximum number of Ph.D. candidates registered in the Department in 1986-1987 was 151, with another 20 in the Joint Program. The entering class in 1986, including those in the Joint Program, was 29. The class arriving in September, 1987 will be 42, including three WHOI students.

We have added four new subjects to our graduate curriculum, to be taught for the first time during the 1987-88 academic year. These subjects [7.31 Biochemistry for Graduate Students (A), 7.34 Topics in Advanced Genetics, 7.81 Frontiers in Modern Plant Biology (A), and 7.82 Selected Topics of Mammalian Development and Genetics] cover important topics that we have not previously been able to include in our graduate curriculum due to difficulties in coordinating the teaching commitments of the faculty members with the interest and expertise to teach them. We are pleased that we are now able to offer these subjects to our graduate students.

RESEARCH

The research activities of the Department are in the areas of biochemistry, genetics, microbiology, cell and developmental biology, immunology, neurobiology, and virology. Individual research projects are described in the publication, Biology Research Summaries, available in the Biology Headquarters Office (56-511).

PERSONNEL

During the past year, Dr. David H. Raulet was promoted to Associate Professor, Drs. Leonard P. Guarente and Monty Kriger were awarded tenure, and Dr. Robert T. Sauer was promoted to Full Professor, effective July 1, 1987.

The Department has made several new appointments to the faculty continuing our expansion in newly developing areas of research.

Dr. Terry Orr-Weaver joined the Department and the Whitehead Institute for Biomedical Research as an Assistant Professor in March, 1987. Dr. Orr-Weaver received the Bachelor's Degree in 1977 from the
University of California, San Diego, and the Ph.D. Degree from Harvard University in 1984. From 1984 until she joined the Department, Dr. Orr-Weaver was a Postdoctoral Fellow in the Department of Embryology at the Carnegie Institution of Washington. Dr. Orr-Weaver's research interests are in the area of the mechanism and regulation of cell growth and division.

Dr. Arthur Lander has accepted a position as Assistant Professor of Neurobiology joint with the Department of Biology and the Department of Brain and Cognitive Sciences. Dr. Lander received the B.S. (summa cum laude) in Molecular Biophysics and Biochemistry in 1979 from Yale College. He received both the Ph.D. Degree in Neuroscience (in June 1985) and the M.D. Degree (in July, 1985) from the University of California, San Francisco. Since 1985 he has been a Postdoctoral Fellow at the Howard Hughes Medical Institute, Center for Neurobiology & Behavior, at the Columbia University College of Physicians & Surgeons. Dr. Lander's research interests lie in the area of the control of axon growth and cell migration in the developing nervous system. He plans to begin his appointment July 1, 1987.

Dr. Hermann Steller also has accepted a position as Assistant Professor of Neurobiology joint with the Department of Biology and the Department of Brain and Cognitive Sciences; he plans to begin his appointment in October 1987. Dr. Steller received the Vordiplom in zoology, botany, chemistry, and physics from the Faculty of Biology, Johann-Wolfgang-Goethe University in Frankfurt in 1978. He received the Ph.D. Degree (summa cum laude) in Molecular Genetics in November, 1984 from the Faculty of Biology at the University of Heidelberg. Since January of 1985 he has been a Postdoctoral Fellow in the Department of Biochemistry at the University of California, Berkeley. Dr. Steller is interested in the molecular mechanisms underlying neuronal development and pattern formation.

Dr. David Page has accepted the position of Assistant Professor to be joint with the Department and the Whitehead Institute for Biomedical Research, and plans to begin his appointment in January of 1988. Dr. Page received the B.A. in Chemistry from Swarthmore College in 1978 and the M.D. Degree (magna cum laude) from the Harvard-MIT Health Sciences and Technology M.D. program in 1984, and has been a Whitehead Fellow since July of 1984. He received the Leon Reznick Award for excellence in research in 1984, and was awarded a MacArthur Prize in 1986. Dr. Page's research interests focus on the molecular biology of the Y chromosome.

Dr. Ruth Lehmann has also accepted a position as Assistant Professor joint with the Department and the Whitehead Institute. She received the Vordiplom (comparable to Bachelor's degree) in Biology from the University of Tübingen in 1976 and the Ph.D. Degree in 1985, also from the University of Tübingen. Dr. Lehmann received the Otto-Hahn medal of the Max-Planck Society in 1985. Since 1985 she has been a Research Associate at the Max-Planck-Institute for Developmental Biology in Tübingen. Dr. Lehmann's research interests are in the area of Drosophila developmental genetics; she plans to take up her appointment in June, 1988.

Dr. Peter Kim plans to take up a position as Assistant Professor joint with the Department and the Whitehead Institute in September, 1988. Dr. Kim received the A.B. in Chemistry (magna cum laude) from Cornell University in 1979, and the Ph.D. Degree in Biochemistry in 1985 from Stanford University. He has been a Whitehead Fellow since 1985. Dr. Kim's current research program focuses on an elucidation of the mechanism of protein folding.

Professor Jonathan King was on sabbatical leave during the spring term, 1987; he remained in Cambridge. Professor Ethan Signer was on sabbatical leave for the 1986-1987 academic year in the laboratory of Dr. Howard Goodman at the Massachusetts General Hospital.

Professor Jack Lawler of the Department of Medicine, Tufts New England Medical Center and St. Elizabeth's Hospital spent a sabbatical year in Professor Richard Hynes's laboratory.

Dr. Anne Summers of the Department of Microbiology at the University of Georgia, Athens, spent her sabbatical year in the laboratory of Professor David Botstein, and Dr. Michael Sela of the Weizmann Institute of Science, Israel, spent his sabbatical year working jointly with Professors Herman Eisen and Alexander Rich.

Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards received by various faculty members in the past year:

Dr. David Baltimore was elected a Foreign Member of the Royal Society.

Dr. David Botstein was named as the first holder of the Earle A. Griswold Professorship. Professor Botstein was chosen because of his "outstanding work in molecular genetics and devoted service to the Department of Biology and the Institute".

Dr. Brent Cochran received one of 18 Searle Scholar Awards for 1987.
Dr. Gerald R. Fink received the Emil Christian Hansen Foundation Award for Microbiological Research "for his successful efforts in creating and developing the molecular genetics of yeast". Professor Fink is also the President-elect of the Genetics Society of America.

Dr. Gobind Khorana was one of 20 scientists to receive the National Medal of Science for his contributions to our understanding of gene structure, membranes, and vision.

Dr. Harvey Lodish was elected to the National Academy of Sciences.

Dr. David H. Raulet was named the first holder of the Robert A. Swanson Assistant Professorship in the Life Sciences in recognition of his outstanding work in immunology, in particular the expression of genes for the T cell receptor during development of the immune system.

Dr. Phillip A. Sharp was one of 10 scientists to win a 1986 Gardner Foundation International Award for outstanding contributions to medical science. Dr. Sharp was honored for discovering how segments of a gene, which may be widely separated in a DNA molecule, are ultimately expressed as a single protein. (Dr. James Darnell of the Rockefeller University was honored for the same discovery).

Dr. Susumu Tonegawa received the 1986 Robert Koch Prize in Immunology and Microbiology for his discovery of somatic rearrangement of immunoglobulin genes and the origins of antibody diversity.

Dr. Robert A. Weinberg received the General Motors Cancer Research Foundation Award for 1987 for his contributions to the fundamental understanding of cancer.

Dr. Richard A. Young was named a Burroughs Wellcome Scholar in Molecular Parasitology for 1987.

Other

It is with regret and sadness that we report the death during the year of Randolph Wei, a senior.

We were also deeply saddened by the death of Professor Bernard Gould this spring. During his 50 years in the Department, Dr. Gould was friend and counsellor to generations of students and many faculty colleagues; he will be deeply missed.

MAURICE S. FOX

RICHARD O. HYNES
Bachelor of Science degrees in Chemistry were awarded this year to 39 undergraduates. Most of the graduates will be attending graduate school in chemistry, medicine, or related disciplines or have taken industrial employment. The Masters of Science degree was awarded to 5 people. A total of 31 Ph.D. degrees were awarded: 9 in September; 15 in February; 7 in June. To date 1852 Ph.D. degrees and 401 Masters degrees have been awarded by the Department.

PERSONNEL

Professor George Buchi was presented the Order of the Rising Sun, Gold Rays with Neck Ribbon Award by the Japanese Consul General on behalf of the government of Japan. This award was given in recognition of Professor Buchi's meritorious services rendered over the years in promoting mutual understanding between the Japanese and American people.

Professor Sylvia Ceyer received the 1987 Edgerton Award, an award given to a junior faculty member at MIT. In addition Professor Ceyer was designated a Camille and Henry Dreyfus Teacher Scholar for 1986.

Professor Alan Davison was awarded with a 1987 Teaching Award from the MIT Graduate Student Council in recognition of exceptional and inspirational teaching.

Professor John Deutch received an honorary doctorate from the University of Lowell.

Professor Stephen Lippard received the annual Inorganic Chemists Award from the American Chemical Society. In addition Professor Lippard received the Remsen Award from the Maryland Section of the American Chemical Society.

Professor Satoru Masamune was given the Arthur C. Cope Scholar Award by the American Chemical Society.

Professor Keith Nelson received the Alfred P. Sloan Award.

Professor Gregory Petsko was awarded the 1987 Pfizer Award in Enzyme Chemistry from the Division of Biological Chemistry of the American Chemical Society.

Professor Jeffrey Steinfeld was elected a fellow of the American Physical Society.

Professor Mark Wrighton was named a fellow of the American Association for the Advancement of Science. In addition Professor Wrighton shared the 1987 Science Council Prize for excellence in undergraduate teaching with Professor Toomie of Mathematics.

ACTIVITIES OF THE DEPARTMENT

Professor Mark Wrighton has been appointed Head of the Chemistry Department succeeding Professor Christopher Walsh effective July 1, 1987.

The Chemistry Department was privileged to host three visiting professors in the past academic year. Professor Alan Sargeson, The Australian National University, was the A.D. Little Visiting Professor. Professor Peter Dervan, California Institute of Technology, and Professor Bert Vallee, Harvard Medical School, visited as T.Y. Shen Visiting Professors of Medicinal Chemistry.
FACULTY AND RESEARCH STAFF

On July 1, 1986, Professor John Southard was promoted to Full Professor and Professor Marcia McNutt to Associate Professor. Also on that date, Professor Peter Molnar resigned as Full Professor to become Senior Research Scientist. New faculty beginning September 1, 1986, were Professor Jason Phipps-Morgan and Professor Daniel Rothman. Professor Edward M. Lorenz retired from the Center for Meteorology and Physical Oceanography on June 30, 1987, after 44 years at MIT. He has been appointed part-time Senior Lecturer, effective July 1, 1987, and will also hold the title of Professor Emeritus from July 1, 1987. Professor Gregory Duckworth resigned on June 30, 1987, to accept a position with Bolt, Beranek and Newman Inc. of Cambridge; he will be Visiting Assistant Professor for the 1987/88 academic year. Both Professor Marcia McNutt and Professor Paola Rizzoli will be promoted to Associate Professor with tenure, effective July 1, 1987. Also on July 1, 1987, Professor Kip Hodges will become untenured Associate Professor, and Dr. Edward Dunham will be promoted to Principal Research Scientist.

Honors

Two American Geophysical Union awards went to EAPS faculty during 1987; the Bucher Medal to Professor William F. Brace, and the VGP Award to Professor Frederick Frey. The Bucher Medal honors original contributions to the basic knowledge of the earth's crust, and the VGP Award honors scientists who have made significant contributions to volcanology, geochemistry, or petrology during the preceding five years. The 1986 Outstanding Paper in Geophysics Award, presented by the Society of Exploration Geophysicists, has been won by Professor Daniel Rothman for a paper that introduced a new Monte Carlo method for the resolution of complex traveltime irregularities that frequently occur in reflection seismic data. Professor Leigh Royden has been awarded a one-year extension, effective July 1, 1987, of the Kerr-McGee Career Development Chair, to which she was appointed for a three-year term on July 1, 1984.

ENROLLMENT

Our graduate enrollment for the academic year just ended was 192, with 77 being Joint Program students at Woods Hole Oceanographic Institution. The undergraduate enrollment was 33. The annual geology/geophysics field camp in California and the astronomy field camp in Arizona took place in January, 1987.

RESEARCH

Geology/Geochemistry

Professors Clark Burchfiel and Leigh Royden spent three weeks mapping in Tibet with Chinese colleagues, in an area which included the north slopes of Mount Everest. They found clear evidence of low-angle normal faulting, indicating northward slumping of higher elements in this generally collisional terrane.

Spectral mineralogy research by Professor Roger G. Burns has included measurements on two shergottite meteorites found in Antarctica, which are believed to have originated from Mars. Glass samples extracted from one of these shergottites had been shown previously to contain trapped gases similar to Martian atmosphere. However, Mossbauer spectra of the glass, individual minerals, and bulk meteorite samples revealed only small proportions of ferric iron, indicating that the shergottites are not derived from the outermost oxidized surface of Mars.

A field, petrologic, and geochemical study of Mauna Kea volcano, Hawaii, was carried out by Professor Fred Frey, and was used to constrain systematic changes in eruption rate during growth of the waning activity of an intraplate "hotspot" volcano. Near the end of the shield building stage, eruption rates decreased markedly, the shallow magma chamber crystallized completely, subsequent magmatic evolution was restricted to moderate pressure (5-10 kb), and eruptions ceased until the density of residual melts was decreased by crystallization and segregation of dense oxide phases.

Professor Tim Grove's studies this year have focussed on the magmatic processes which produced compositionally-zoned basalt to andesite lava flows at Medicine Lake volcano, northern California. Within upper crustal level magma chambers, a large amount of fractional crystallization of mantle-derived basalt produces heat that melts granitic crust. The bulk of the basalt magma in the chamber remains chemically isolated from the melted crust, until a later magmatic injection recharges the system, mixing the melted crust and differentiated basalt with the fresh mantle-derived basalt melt. The compositional zoning in the erupted lavas preserves a record of this magma chamber stratigraphy, and shows that basalt-silicic crust interaction in subduction zone environments occurs through processes in which heat and chemical diffusion are decoupled.
Professor Stan Hart has continued to delineate the large-scale Sr, Nd, and Pb isotopic anomaly in the southern hemisphere mantle. With few exceptions, this "DUPAL" anomaly is indeed restricted to Southern Latitudes; limited data from polar regions (North and South) shows these also to be anomalous, but with a signature which is complementary and inverse to the DUPAL signature. At least one component of the DUPAL anomaly has been traced to delaminated subcontinental lithosphere; another component probably represents recycled oceanic crust and sediment.

Professor Kip Hodges' research focused on the kinematics of extensional basin development in southeastern California and on the thermal evolution of the Himalaya. In California, mapping in conjunction with the graduate and undergraduate geology field camps has demonstrated that the growth faults associated with basin development in the Death Valley area have complex curvilinear geometries and experience distinct phases of movement, each producing a distinctive sedimentological signature in the developing basin. In Nepal, India, and Southern Tibet, the thermal evolution of the Greater Himalayan crystalline rocks appears to have been influenced by (1) large-scale thrust faulting, associated with India-Asia continental collision, (2) the intrusion of large volumes of granitic material, and (3) the development of N-dipping, low-angle extensional faults.

Using the ion microprobe, Dr. Nobu Shimizu analyzed clinopyroxene and orthopyroxene in spinel lherzolite nodules from Salt Lake Crater, Oahu, for the major and trace element compositions. The trace element abundance patterns in the pyroxenes, and hence the bulk lherzolites, are characterized by depletion in Ti and Zr relative to REE, revealing an astounding similarity to island arc magmas. This observation has led to a discovery that spinel lherzolite mantle from the worldwide localities indeed carries the same feature. It is suggested that one of the most diagnostic features of island-arc magmas can be derived simply by partial melting of ordinary spinel lherzolite mantle without requiring any special mineral phases during partial melting or special source mantle, as commonly invoked.

Professor John Southard has continued his laboratory studies of the physics of sedimentary processes. By a new technique for measuring the distribution of jump lengths in sand movement by wind, he has placed constraints on the physics of saltating sand grains and has developed a new model for the dynamics of wind ripples.

Geophysics

Dr. Arthur Cheng has developed a method to determine shear wave velocities in ocean-bottom sediment by using a full waveform inversion algorithm on acoustic logging data. This technique provides previously unobtainable in situ measurements of shear wave velocities in the sediment column. Shear wave properties are important for the study of seismic wave propagation along the ocean bottom, as well as the coupling of ocean-bottom seismometers.

Dr. Vernon Cormier has implemented a technique for connecting 2- and 3-D structure with 1-D or radially symmetric earth structure for use with asymptotic methods of synthesizing seismic body waves. Future applications include the prediction of the multipathing and shadowing of body waves occurring within descending lithospheric slabs and prediction of pulse complexity of body waves interacting with heterogeneities at the base of the mantle.

Professor Gregory Duckworth has developed inversion procedures to estimate under-ice surface scattering parameters and effective attenuation in the sea-bed of the Arctic Ocean using acoustic data from explosions. For the same region, he has developed an acoustic ice floe tracking system capable of measuring ice drift motions due to internal waves. These measurements have shown that internal wave activity in the upper Arctic Ocean is ten times less energetic than in the main thermocline of temperate oceans.

Professor Brian Evans has investigated solution transfer processes in granular quartz and halite aggregates. In situ observations of crack healing in single crystals of halite are useful in identifying transport paths and in constraining solution transfer kinetics. Both minerals show considerable similarity to sintering processes in metals and ceramics.

Professor Thomas Jordan and his students have been working on a variety of problems related to the structure and dynamics of the earth's mantle. Lind Gee and Professor Jordan have developed techniques for isolating structural information from the complex waveforms of multiply reflected shear waves; they have observed that the propagation times of these waves depend on their polarization, a phenomenon known as shear-wave splitting. They relate this splitting to small-scale layering in the continental upper mantle inherited from the formation of the cratonic nuclei several thousand million years ago. Justin Revenaugh and Professor Jordan have discovered a new set of seismic phases which represent energy reflected from internal discontinuities at depths of 400 and 650 km; measurements from these phases are yielding constraints on the properties of the transition zone difficult to observe by standard methods.

Dr. Robert King, Dr. Yehuda Bock, and Professor Thomas Jordan, in collaboration with colleagues at Caltech, UCLA, and UCSD, are using radio observations of the Global Positioning System (GPS) satellites to study crustal deformation in central and southern California, primarily west of the San Andreas Fault. In the first of a series of measurements to be performed over the next five years, they measured the relative positions of 20 sites with a precision of 5-15 mm.
In his core motion studies, Professor Ted Madden is attempting to distinguish between convected features (westward drift) and wave propagation phenomena by examining the time variations of the velocities inferred.

Professor Marcia McNutt and four MIT graduate students spent the month of April on an oceanographic expedition to survey the Marquesas Islands. As a result of their work, these islands will be second only to the Hawaiian group in being the best known island chain, in a geophysical sense, in the Pacific Ocean. This expedition is part of a longer-term effort by Professor McNutt to understand the factors contributing to the excessive rate of midplate volcanism in French Polynesia.

With graduate student Joann Stock, Dr. Peter Molnar has located a previously unrecognized plate boundary in what is now the Antarctic plate, and, having quantified the motion across it, they have been able to show that the hotspots in the Atlantic and Indian Oceans move in respect to the Hawaiian hotspot at rates of 10 to 20 mm/year. With Federico Pardo-Casas, Dr. Molnar has shown that variations in the rate of subduction of the Nazca plate beneath South America correlate with phases of intense and quiescent tectonic activity in the Andes.

Professor Jason Phipps-Morgan has continued his research on the thermal and mechanical structure of mid-ocean spreading centers while starting new research projects on small-scale convection within the upper mantle and on melt migration within the mantle. The latter work has led to the exciting possibility that mantle deformation induces an anisotropic melt permeability to the mantle, which in turn is the cause of the narrow spatial zone of volcanism at mid-ocean spreading centers and oceanic hotspots.

Professor Daniel Rothman has developed a new numerical method for modeling fluid flow in rocks. The technique, based on lattice-gas models of hydrodynamics, provides the ability to study fluid transport properties within a rock's porous microstructure. Further work should provide new insight into the factors governing the permeability of rocks in addition to providing a method for the estimation of permeability itself.

Professor Gene Simmons has continued to work on the role of microcracks in the transport and/or retention of uranium and thorium on rocks. In addition, he has used gravity and other data in central New Hampshire to relate earthquakes to surface faults.

Professor Sean Solomon and his students have been utilizing networks of ocean-bottom seismometers and seismic tomography techniques to determine the three-dimensional structure of the crust along mid-ocean ridges. They discovered a narrow zone of low crustal velocities beneath the central inner floor of the Mid-Atlantic Ridge median valley near 23°N; this zone presumably marks the axis of most recent crustal accretion. They have recently returned from an experiment on a large-offset transform fault in the Atlantic, and an expedition to image the three-dimensional structure of the postulated crustal magma chamber along the East Pacific Rise is planned for January, 1988.

Professor M. Nafi Toksoz has been studying the tectonic evolution of the eastern Mediterranean due to the convergence of the African and Arabian plates northwards against Eurasia. This region is one of the world's most accessible laboratories for the study of continental collisions.

**Meteorology**

Professor Randall Dole has performed observational analyses demonstrating that major cases of atmospheric persistence are associated with a relatively small number of recurrent large-scale flow patterns. These flow patterns are related to major anomalies in surface temperatures and significant shifts in the locations of maximum storm activity over the Northern Hemisphere.

Over the past year Professor Kerry Emanuel has worked on air-sea interaction theories for the development of long-period oscillations of the equatorial atmosphere and, at the opposite ends of the earth, of small-scale cyclones that form over the polar oceans during the arctic night.

Dr. Bruce Fegley has used observations of trace gases which are mixed upward from the interior of Jupiter to constrain the water vapor and total oxygen abundances on the planet. This work demonstrates that the observed water vapor depletions in the troposphere are a meteorological effect and not a planetary depletion in water and total oxygen.

Professor Richard Lindzen is studying aspects of dynamic meteorology ranging from the basic mechanism of shear instability to the reasons for the 100 k year cycles in glaciation. Most recently, he has developed simple models for the air-sea interaction over the tropical oceans, for the generation of planetary scale transient disturbances in the atmosphere, and for explaining why the Pole-Equator temperature difference is what it is.

Professor Edward Lorenz has been investigating the existence of a "slow manifold" - a postulated family of atmospheric states which are devoid of rapid oscillations - by means of a mathematical model. The model atmosphere is found to possess an invariant manifold which has some of the desired properties, but is not unequivocally slow.
Professor Reginald Newell's group participated in the NASA program at Darwin, Australia, in January-February, 1987, to measure the passage of air from the troposphere to the stratosphere. First results, from high-flying aircraft measurements of water vapor, ozone and temperature, suggest that the stratosphere is kept dry by the large-scale organized transfer of air through the tropical tropopause region rather than by small-scale motions accompanying individual convective clouds.

Professor Ronald Prinn and his colleagues have utilized data from their global network of measurement stations to deduce by inverse methods that the USSR and China are emitting $71 \pm 22$ kilotons per year of the refrigerant freon $CF_2Cl_2$. This freon is the major potential contributor to ozone depletion, and these countries have declined to disclose their annual $CF_2Cl_2$ production data.

Professor Peter Stone has been investigating how the role of eddies in the atmosphere is affected by dissipation. The effect of the eddies ranges between two extremes, depending on whether frictional or diabatic effects dominate. In one extreme the total heat transport is entirely due to the eddies, and in the other extreme the eddies do not affect the total heat transport. The atmosphere's regime is very close to the former extreme, and Professor Stone's results suggest ways in which climate models can be correspondingly simplified.

Professor Earle Williams is studying causes for anomalous positive cloud to ground lightning, the causes and electrical manifestations of microbursts in thunderstorms, and the structure of lightning with radar.

Oceanography

Professor Ed Boyle has documented the response of the global ocean to anthropogenic lead emissions. He obtained measurements of lead in seawater over the last seven years, and measurements of lead in annually-banded corals over the last 100 years. Near Bermuda, lead increases from about 1880 to 1920, in pace with the U.S. industrial revolution, leveled off until the 1950s when usage of leaded gasoline increased dramatically. Since 1970, the lead content of the ocean has been decreasing in response to the phasing out of leaded gasoline.

Professor John Edmond extended his hot spring work on a slow-spreading ridge (Mid-Atlantic between 22 and 26 N) to two enormous hot spring fields at depths of about 3600 meters. Their temperatures (350 C) and solution chemistries are almost identical to what has been seen at numerous locations on the East Pacific Rise. There is no evidence for reaction with a deep-seated magma chamber (6 km), and given the size of the deposits (order 5 million tonnes), they cannot be "anomalous".

Professor Glenn Flierl has developed new theoretical models for the meandering of the Gulf Stream. Based on approximating the front as a discontinuity, these models permit analytical solutions in the long wave or small amplitude limits and can be solved with fairly simple numerical techniques. Comparison of these models with observations will be carried out during the SYNOP experiment.

Aluminum concentrations determined in seawater samples collected in the Mediterranean and the Atlantic by Dr. Christopher Measures, during a cruise in the Strait of Gibraltar, were used to show that less than 10 percent of the Mediterranean outflow plume was composed of Western Mediterranean Deep Water. The ability to calculate the makeup of the outflowing plume is important in gaining a better understanding of the ventilation of the Mediterranean.

Professor Paola Rizzoli has continued her study on the assimilation of altimetric and tomographic data into Models of the Ocean General Circulation (OGCM). Data assimilation into OGCM is one of the central objectives of WOCE (the World Ocean Circulation Experiment). She has found that (1) density (or temperature) data assimilated into the OGCM significantly improve the model's estimates if the data are measured along tomographic sections which are meridional, long, and located at distance from the western boundaries of ocean basins, and (2) the transients created by the assimilation of data measured only locally (i.e. along sections) deteriorate the model's estimates on the short time scale, but their continuous assimilation improves the estimate of the global climatological state.

Professor Carl Wunsch and co-workers have been formulating oceanic models using control theory methods, the purpose of employing altimetric observations for determination of the general circulation. The use of control methods permits much more convenient recursive updating and sensitivity determination of the models to particular data types.

Professor William Young is currently working on the stability of ocean fronts. Besides being an important problem in its own right, it serves to illustrate the fundamental mechanism of shear flow instability.

Planetary Sciences

Professor Charles Counselman's group uses portable equipment which receives radio signals from satellites to measure regional displacements of the earth's crust. Accuracy of 1 part in 10^7 has now been demonstrated, by comparison with satellite laser ranging measurements in southern California.
This spring, Professor Jim Elliot, Dr. Richard French, Dr. Linda French, and their students observed an unusual occultation by Uranus and its ring system that lasted for four days, from a network of observatories located in Chile, South Africa, Hawaii, and Australia. These observations will be particularly useful for understanding the longitudinal structure of the rings and the horizontal structure of the Uranian upper atmosphere.

Professor David Jewitt has used a state-of-the-art optical photometer to investigate the nucleus of periodic comet Encke. The observations provide a direct test of the Whipple & Sekanina precessing oblate spheroid nucleus model. The properties of the nucleus indicated by the direct photometry are substantially different from the properties derived from the model. The model may need to be reconsidered.

Professor Gordon Pettengill continues his heavy involvement as Principal Investigator in the Venus Radar Mapping (Magellan) mission. In support of this work he is analyzing data obtained by the Soviets, as well as earth-based radiometric observations obtained from the Very Large Array in the US.

Professor Jack Wisdom has found that all irregularly-shaped natural satellites spend a period of time tumbling chaotically just before the spin is captured into the synchronous rotation resonance where the same face of the satellite is always pointed toward the planet. This is a significant modification of the standard picture of the tidal evolution of the rotations of the natural satellites. The period of chaotic tumbling can have a significant effect on the orbital evolution of small natural satellites. He has also been studying the equilibrium properties of planetary rings through numerical simulations.
There were 219 undergraduates majoring in mathematics and 128 graduate students. Of the undergraduate majors, 162 were registered for the general mathematics degree (XVIII), and 57 for the mathematics with computer science degree (XVIII-C). The Bachelor of Science was awarded to 68 students, including 14 second majors. There were two recipients of the Master of Science, one in pure mathematics and one in applied mathematics. Of the 22 recipients of the Doctor of Philosophy in mathematics, 13 were in pure mathematics and nine in applied mathematics.

The principal theme of freshman calculus this year was an effort via "linking" to get closer relations with the freshman physics course: the same set of students were put into some pairs of calculus and physics recitations, and their instructors were encouraged to meet over lunch to discuss problems with the syllabus and the students they had in common. Some useful information about the syllabus emerged; student opinion about the experiment was somewhat mixed, and it proved difficult to keep the same set of students together. Efforts at relating calculus and physics will continue.

On the national scene, there will be committees meeting to discuss possible calculus reform, and our department will be participating in these. Part of this is sparked by the new generation of pocket calculators, which permit on-the-spot symbol manipulation, graphing of functions, and numerical integration.

In the large differential equations course, this was the first year when all students got Athena problems for homework. Most welcomed this material; it will be further developed during the coming year. It is also likely some efforts to incorporate Athena into calculus may be made on a small-scale basis.

The advanced calculus course developed by Professor Strang (Mathematical Methods for Engineers, 18.085-6) continues to grow and be adopted as a requirement by departments.

There are several new subjects under consideration for development to satisfy MIT's proposed new science distribution requirement, and next year will see work on at least two of them.

In the graduate program, the principal change has been the requirement of a written thesis proposal for all students (pure as well as applied), within six months after they pass their oral examinations. This seems to be producing the desired effect of getting students thinking about research as soon as possible after their formal course requirements are over.

FACULTY

Robert MacPherson will be joining the faculty in September as Professor of Pure Mathematics. Professor MacPherson formerly held an appointment at Brown University. His fields are topology, algebraic and differential geometry.

Associate Professor Sy D. Friedman was promoted to Associate Professor with Tenure. His field is logic and set theory; his recent work has been in set-theoretical coding.

Assistant Professor L. Nicholas Trefethen was promoted to Associate Professor. His specialty is numerical analysis.

Institute Professor C.C. Lin retired in June. His forty years at MIT were devoted to fundamental work in fluid mechanics, particularly stability theory, and to astrophysics, where he is known for his density wave theory of galactic structure. Professor Lin has been president of SIAM, and was several years ago the Killian lecturer at MIT. A three-day symposium in June to honor him was attended by applied mathematicians from all over the world.

We were saddened to learn of the sudden death of Professor Emeritus George Wadsworth. He died of heart failure in April at the age of 78. Professor Wadsworth retired in 1974 after 39 years of teaching in the Mathematics Department. He was known for his work in probability and statistics, and was one of the founders of the field of operations research.

Associate Professor Anders Björner resigned to accept a professorship at the Royal Institute of Technology in Stockholm, and Associate Professor Frank Morgan has accepted a position at Williams College.
Faculty on leave during the year were: Nesmith Ankeny (fall), Daniel Freedman (spring, Princeton), Harvey Greenspan (spring), Victor Guillemin (spring), Daniel Quillen (year, Oxford), Irving Segal (spring), Harold Stark (spring, UCSD), Michele Vergne (spring, CNRS, France), Anders Björner (year, Royal Institute of Technology, Stockholm), Frank Morgan (year, Stanford).

Visiting the department this year were: Zoltan Furedi (Math. Institute, Hungarian Academy of Science), Grete Ljung (Boston University), Iris Mack (Ph.D., Harvard), Yves Pomeau (CNRS, Paris).

Professor Richard Melrose will succeed Professor Franklin Peterson as Chairman of the Pure Mathematics Committee. Professor Peterson has served in this position for the last three years. Professor Willem Malkus will continue as Chairman of the Applied Mathematics Committee, Professor David Vogan as Chairman of the Undergraduate Mathematics Committee, Professor James Munkres as Chairman of Undergraduate Advisors, and Professor Sigurdur Helgason as Chairman of the Graduate Committee.

FACULTY HONORS AND AWARDS

Professor Sigurdur Helgason received an honorary doctorate from the University of Iceland, by unanimous vote of the Science Faculty. The degree was given as part of the University's celebration of its 75th anniversary; it grants honorary degrees only once every 25 years.

Professor Alar Toomre received the School of Science Teaching Prize (jointly with Professor Mark Wrighton of Chemistry). The prize is awarded on the basis of both student and faculty testimonials. Professor Toomre, a mathematical astronomer and one of the recipients of the MacArthur prize, is widely known for the enthusiastic and dynamic lecturing style he brings to large classes in differential equations, complex variables, advanced calculus, and applied mathematics; he is also the designer of many of these courses in the form in which they are currently offered.

Professor Michael Artin is the editor-in-chief of the elite new Journal of the American Mathematical Society. Its first issue will appear in January 1988 to celebrate the 100th anniversary of the AMS.

Professor Victor Guillemin is this year's winner of the Graduate Student Council Teaching Award in the Department of Mathematics.

Professor Gian-Carlo Rota has been chosen chairman-elect of the Mathematics Section of the American Association for the Advancement of Science.

Professor Daniel Freedman received a Guggenheim fellowship.

Assistant Professor David Shmoys received a Presidential Young Investigator Award. He is the fourth member of the department to receive this award. His field is theoretical computer science.

STUDENTS

Three graduate students, Samuel Evens, Hisayosi Matumoto, and Christopher Stover were selected by a national committee to receive Alfred P. Sloan Doctoral Dissertation Fellowships.

The annual Jon A. Bucsela Prize, given by the Mathematics Department in recognition of distinguished scholastic achievement, professional promise, and enthusiasm for mathematics, was awarded to senior undergraduates Avrim L. Blum and Eric P. Twietmeyer.

ARTHUR P. MATTUCK
In spite of financial stringencies during the past year, all major research programs in the Department have remained active and some important new initiatives have been started, as described in the detailed accounts later in this report. The Department has continued to address the challenge it faces as a major component of the MIT educational program.

The members of the Physics Department continue to provide leadership for the major MIT interdepartmental laboratories. At present the Directors of the Laboratory for Nuclear Science (LNS), Bates Linear Accelerator (BLA), Center for Materials Science and Engineering (CMSE), National Magnet Laboratory (NML), Spectroscopy Laboratory, and Plasma Fusion Center (PFC) are members of the Physics Department, as well as the Associate Director of the Research Laboratory of Electronics.

In 1986-87 the total number of the Faculty was 89. The following members of the Faculty received promotions: to Associate Professor with Tenure, Edward Farhi; to Principal Research Scientist, Edward Cheng. Six new Assistant Professors joined our Faculty: Edmund Bertschinger, Susan Cooper, Gregor Herten, Mehran Kardar, Aneesh Manohar and Barton Zwiebach. Three members of the Faculty retired: Alan Barrett, Martin Deutsch and Herman Feshbach. One Faculty member, Scott Tremaine, and one Senior Research Scientist, Yaacov Shipira, resigned.

Faculty on leaves or sabbaticals during the year included Professors Charles Alcock, Alan Barrett, Aron Bernstein, Alan Guth, Charles Horowitz, Kerson Huang, Robert Jaffe, John King, Earl Lomon, Miklos Porkolab, Lawrence Rosenson, Steven Stahler, Malcolm Strandberg, Scott Tremaine, and Felix Villars. Faculty Sloan Fellows included Professors Charles Alcock, Edward Farhi, Gabriel Kotliar and John Tonry.

Institute Professor Emeritus Bruno Rossi was co-recipient of the Wolf Prize. The late Professor Emeritus M. Stanley Livingston was honored posthumously with the 1986 Enrico Fermi Award [United States Department of Energy (DOE)]. Other awards and honors received by Physics Faculty were the following: Professor Robert Birgeneau, Oliver J. Buckley Prize [The American Physical Society (APS)], Loeb Lecturer (Harvard University); Professor Bruno Coppi, Member, I Magnifici Cento (Panorama Magazine, Italy); Professor Ronald Davidson, 1986 Distinguished Associates Award (DOE), 1987 Leadership Award (Fusion Power Associates); Institute Professor Mildred Dresselhaus, 1986 Phi Beta Kappa Lecturer, Member of the Governing Board of the National Research Council; Professor Farhi, Class of 1956 Career Development Professorship (renewal); Professor Alan Guth, Fellow of the American Academy of Arts and Sciences; Professor Uno Ingard, 1986 Best Paper Award (Acoustics Division of American Society of Mechanical Engineers); Professors Jaffe and Patrick Lee, Fellows (APS); Professor Daniel Kleppner, Member, National Academy of Sciences, Loeb Lecturer (Harvard University), Edward Condon Lecturer (University of Colorado); Professor Kotliar, 1987 Young Investigator Award [National Science Foundation (NSF)]. Professor Margaret MacVicar, Dana Award (Charles A. Dana Foundation); Professor Philip Morrison, Honorary Doctorate (Amherst College); Professor Toyoichi Tanaka, 1987 Award of the Polymer Society of Japan; Senior Research Scientist Alan J. Lazarus, IAP Academics Award.

With regard to student honors, Jennifer Weissman, a senior, discovered a new comet which carries the name of Weissman-Skiff. Eight students were elected to Phi Beta Kappa: Ivan H. Deutsch, Andrew B. Dobrzeniecki, Andrea M. Ghez, Chung-Pei Ma, Stephen I. Shefsky, David L. Shupe, Paul N. Watts and William J. Wedemeyer. The Orloff Prize for Physics, an annual prize given by the parents of Joel M. Orloff, Class of 1978, in his memory, was awarded to Mark Wang. Douglas Beck was awarded the Demos Prize, given annually for outstanding doctoral research carried at the BLA.

EDUCATIONAL ACHIEVEMENTS

The Department has continued to maintain a relatively constant number of graduate and undergraduate students, as well as a relatively constant number of credit units per faculty member. This year, the number of undergraduate majors was 245, an increase of 22, and the number of graduate students was 289. The number of degrees awarded totaled 62 S.B. 8 S.M. and 40 Ph.D.
CURRENT RESEARCH

Astrophysics Division

Research in the Astrophysics Division is concerned with the observation and analysis of a wide variety of astrophysical phenomena including the interactions of the solar wind with planetary magnetospheres, the structure and evolution of stars and binary systems, quasi-periodic oscillations in the brightness of X-ray stars, hot gas in clusters of galaxies, the microwave background radiation, gravitational radiation, cosmic strings, and the development of structure in the early universe. Major efforts are devoted to the instrumentation and use of ground-based and space-based observatories. Theoretical research is carried out on topics ranging from plasma physics in the solar system, to cosmology and the large-scale structure of the universe.

1. High Energy Astrophysics. Analysis continues on data obtained from the Einstein X-Ray Observatory during its period of operation from 1978 to 1981. Current topics under investigation include the hot gas in elliptical galaxies, the X-ray optical spectra of cooling flows in clusters of galaxies, time variability and X-ray spectra of active galactic nuclei and quasars, and the hot plasma in supernova remnants. In related research, optical observations of giant elliptical galaxies which are known to be diffuse sources of X-rays have been carried out with the new 2.4 m telescope at the McGraw-Hill Observatory, and numerical models of cooling flows have been computed for comparison with the data.

Extensive use has been made of data from the European X-Ray Observatory EXOSAT to study low-mass X-ray binaries and the phenomenon of quasi-periodic oscillations (QPO) in the X-ray emission of these sources. Nine more sources have been found which exhibit this phenomenon in the range from ~100 Hz. In a related investigation, EXOSAT observations of X-ray bursts from several of these sources have led to improved determinations of the mass-radius relation of neutron stars.

The systemic search for the optical counterparts of X-ray sources detected in the all-sky survey carried out during 1977-79 with the orbiting High Energy Astrophysical Observatory HEAO-1 continues to yield about 20 new identifications per year. The search is being conducted with telescopes in both the Northern and Southern Hemispheres and includes extensive collaboration with the Australian National University.

Investigation of the atmospheric structure of the giant O-type star which is companion to the X-ray pulsar, Cen X-3, has demonstrated the presence of a hot coronal layer at the base of the intense stellar wind emanating from the O-star. This conclusion, based on an analysis of data from the SAS 3 satellite, is substantially at odds with widely held ideas about the atmospheric structure of early-type stars.

Work continues on three major instrument development projects for future X-ray satellite observatories. MIT is one of three institutions that has been selected for participation in the X-ray Timing Explorer Project (XTE). The MIT Group is responsible for development of the all-sky survey instrument and for the data system. The Group is also directing the development of the Bragg Crystal Spectrometer which is one of the four focal plane instruments selected for the Advanced X-Ray Astrophysics Facility (AXAF). Primary responsibility for development of the imaging spectrometer, also selected for the AXAF, has been assigned to MIT.

The first set of instruments for the "Explosive Transient Camera" (ETC) has been operated for several extended periods at an MIT site at the Kitt Peak National Observatory in Arizona. The ETC is designed to detect brief outbursts of light from celestial objects. The purpose of the facility is to locate and identify sources while, at the same time, opening a wide new range of astronomical parameter space to exploration.

2. Radio Astronomy. A "counter-jet" has been discovered in the radio galaxy Cygnus A. This follows the earlier discovery of the more prominent relativistic jet that emanates from the other side of the active galactic nucleus. Both results have been obtained with the Very Large Array (VLA) through the use of radically new methods of observing and image processing. A detailed map of the polarization of the radio emission has also been completed. One of the largest observing programs ever undertaken at the VLA for the purpose of extending these methods to a large selection of radio galaxies has now begun.

The Group has been carrying out an extensive search for new gravitationally-lensed quasars in collaboration with colleagues at Princeton and Cal Tech. One prime example, Q0023+171, has been discovered, and half a dozen promising new candidate objects are being studied in detail. About 4,000 radio maps, taken with the VLA, are being processed as a part of their
program. In another area, a successful series of VLBI experiments have been conducted for
the purpose of establishing the 7 mm radio band for standard VLBI operations. A synthe-
sized VLBI map at 7 mm of the active galaxy 3C84 (Perseus A) has been prepared. Having an
angular resolution of 140 microarc-seconds, it is the most highly detailed radio map ever
made of that unusual object. A member of the Group also continues as US Principal Investi-
gator for the Quasat satellite project, a joint US-European project aimed at establishing
an orbiting VLBI station for use in conjunction with earth-based stations to achieve higher
angular resolution in VLBI radio maps than can be obtained with earth-based stations alone.

3. Optical Astronomy. Investigations of the dynamical properties of elliptical galaxies
and the problems of the nature and distribution of "dark matter" have been made with
optical observations at Palomar and other large telescopes. This work has been facilitated
by the development at MIT of a powerful software system for image display and analysis.

4. Gravitational Radiation. The 1.5 m prototype interferometer gravitational wave antenna
has been used in an observation to set limits on gravitational radiation from a hypothetical
pulsar that may have been formed as a result of the 1987A supernova explosion. The system
was not operating at the time when the neutrino signals arrived at earth. Work continues
on design and construction of the new 5 m prototype which is intended to be a development
tool for the large baseline system being planned.

The large baseline system, consisting of two antennae, one in Maine and the other in
California, is a joint effort with Cal Tech. The project has been under study for the
past six years and is expected to enter a detailed engineering phase in 1988 with con-
struction beginning in 1989. An independent panel of physicists commissioned by the NSF
has reviewed and endorsed the project.

5. Cosmology. Instruments for the Cosmic Background Explorer (COBE) satellite mission are
undergoing preflight testing with the third and final cryogenic test being scheduled for
September 1987. The MIT Group continues to be closely associated with the effort on the
Far Infrared Absolute Spectrometer (FIRAS) which will be able to measure Cosmic Background
Radiation (CBR) deviations from a Planck distribution of less than one percent with tightly
controlled systematic errors. MIT involvement with Diffuse Infrared Background Experiment
(DIRBE) is in the area of detector characterization and stability in the radiation en-
vironment of the COBE orbit. The COBE satellite is currently being rebuilt for a Delta
launch, with a target launch date of March 1989.

A four-channel balloon-borne CBR anistropy instrument is being developed to measure CBR
anistropies in the spectral range 4 to 25 cm⁻¹ on angular scales of 4° to 180° with a
sensitivity of a few parts in 10⁵. The flight gondola and electronics are being
constructed, with the first flight scheduled for October 1987.

A new effort of the Group centers around a 19 GHz balloon-borne maser instrument which
will be flown twice in the Southern Hemisphere to generate a complete map of the sky.

Some of the deepest problems of the early universe and the evolution of structure involve
the phenomena of chaos. It has been demonstrated experimentally that for two frequency
quasiperiodicity there are new forms of this transition which are not accounted for or
anticipated by current theory. Further work on this problem is being undertaken because of
its great potential importance for the understanding of hydrodynamic turbulence in
astrophysics.

6. Theoretical Astrophysics. The orbital period of a previously much studied X-ray binary
was recently found to be approximately 11 minutes, the shortest of any known orbital period
of a binary star system. The investigation of the evolution of this binary system under
the influence of the emission of gravitational radiation and mass transfer to the neutron
star is now being carried out.

A new theoretical model for the recently exploded supernova in the Large Magellanic Cloud
is also being developed. The unique features of this model are that it invokes a red
giant star that transferred matter to a stellar companion which is the progenitor of the
supernova and a rapidly spinning remnant neutron star that is presently powering the energy
output of the supernova.

Detailed Monte Carlo studies of the possible influence of primordial cosmic strings on the
evolution of structure in the early universe are being carried out. Another project has
been the investigation of the effect of thermal conductivity on the accretion of inter-
galactic gas by giant elliptical galaxies in a study that ties in closely with recent
X-ray observations of the hot gas in clusters of galaxies.
7. Space Plasma Physics. Studies of solar system plasmas, which can be probed directly, provide unique insights into general problems in plasma physics, particularly those involving dilute plasmas. The MIT effort in this field includes both an experimental program in the measurement of space plasmas throughout the solar system, and a theoretical program in geoplasma research.

Plasmas in five planetary magnetospheres have been sampled directly (those of Mercury, Earth, Jupiter, Saturn and Uranus) with instruments developed at MIT. Current efforts in observational research concern the sources, sinks, transport; and energization of plasmas in the magnetospheres of the outer planets. Particular attention in the past year has been focused on Uranus, which is unique in the solar system because of the unusual 60 degree tilt angle between the magnetic dipole axis and the rotation axis of the planet. In terms of heliospheric physics, one of the major areas of study continues to be the structure of the solar wind in the outer solar system based on Voyager 2 data, and in particular how that structure affects the solar cycle modulation of galactic cosmic rays. In addition, work continues on data obtained during the encounter of the Giotto spacecraft with Halley's comet in 1986, both in the areas of the composition of the cometary material and its interaction with the solar wind.

A new Center of Theoretical Geoplasma Research has recently been established under the University Research Initiative program of the Air Force Office of Scientific Research. Its programs will be interdisciplinary, and it will provide support for the work of theoretical plasma physicists, ionospheric and magnetospheric scientists, mathematical physicists, and numerical analysts, interacting with one another and with the international community (particularly experimental groups) engaged in space plasma activities. Current research topics include particle acceleration and diffusion, magnetospheric and ionospheric turbulence, wave generation and propagation in the geoplasma environment, auroral ionospheric-magnetospheric processes, and the non-classical polar wind.

Atomic, Condensed Matter, and Plasma Physics Division

1. Atomic, Molecular and Laser Physics. The study of free atoms at temperatures in the millikelvin and microkelvin regime has been spurred by laser techniques for atom trapping and cooling. As laser methods are not well suited to working with hydrogen, a different technique has been used. By precooing the hydrogen in a dilution refrigerator, the Group has confined more than $5 \times 10^{12}$ atoms in a static magnetic trap, evaporatively cooled them to 40 mK, and kept them isolated from any walls for over 20 minutes. Further evaporative cooling should be able to lower the temperature of the atoms below 100 μK.

Dramatic advances have been made in the trapping of neutral atoms. At MIT we demonstrated the continuous loading of sodium atoms into a superconducting magnetic trap in which atoms with electron spin up were confined to a local minimum in the magnetic field. More than $10^9$ atoms were trapped for about 100 sec. An MIT Group demonstrated, in collaboration with an AT & T Bell Laboratory Group, an atom trap based on the scattering force of near-resonant laser light. A 0.3 mm ball of sodium with a density of more than $10^{11}$ cm$^{-3}$ was observed for about 100 sec. In both experiments the atoms were cooled to about one millikelvin by laser light. These experiments advance the state-of-the-art in both number of atoms trapped and the confinement time by two to four orders of magnitude, and should permit interesting experiments to be conducted on these isolated, ultracold atomic gasses.

2. Condensed Matter Physics. An interdisciplinary effort has been developed involving physicists, engineers and materials scientists in the exploration of the origin of the very high superconducting transition temperatures in transition-metal-oxides. Predictions of the MIT theorists are being tested by neutron scattering, electronic conductivity and optical measurements.

The existence of a new neutron Spin-Pendellosung resonance effect for neutrons diffracting in a crystal has been confirmed with experiments in the Neutron Diffraction Laboratory. Within a diffracting crystal there occurs a periodic variation of energy flow direction as a function of penetration depth in the crystal (Pendellosung oscillation). When this is coupled with Larmor spin rotation of the neutron under resonant conditions, normal spin-orbit scattering contributions become greatly enhanced and measurable. This has been demonstrated for the case of Schwinger scattering (magnetic dipole - electric charge interaction) in silicon which is unmeasurable by usual methods. The use of this resonance technique opens a new regime of sensitivity in searching for other suspected forms of spin-orbit interactions.

MIT theorists are continuing their calculations to predict the structure of solids using only the atomic number of the constituent atoms as input. The results have been very exciting, leading to a prediction of surface reconstruction geometries, surface reaction
pathways, surface chemisorption geometries, bulk defect geometries and phase transition critical temperatures.

Theoretical work in statistical mechanics has concentrated, within the last year, on systems that are frustrated via competing microscopic interactions. In such liquid crystal systems, it now appears that previous theory can be extended to include, in addition to the nematic and smectic $A_1$ and $A_2$ phases, the experimentally observed smectic $A_1$ and $A_2$ phases. Progress has been made in modelling the phenomenon of inter-smectic wetting due to surface conditions. Microscopic theories for frustrated magnetic systems have also been constructed, in particular for a metamagnetic system that clearly exhibits a mechanism for reentrant phase transitions.

Last year a theoretical study of statistical mechanics and dynamics of polymeric surfaces was initiated. By generalizing phenomenological and scaling theories of polymers the rich behavior of such manifolds was explored. Also a novel $\epsilon$-expansion procedure was developed that provides a unified treatment of polymers and surfaces.

The behavior of interfaces in random systems has generated considerable recent interest. The replica method was used to treat exactly interfaces in the $2d$ with random-bond impurities. Critical behavior of the free energy, and its cumulants, was thus obtained completely for interface-driven phase transitions. Interfaces, and linear defects, in $3d$ for both random-bond and random-field impurities were also studied by numerical simulations.

Studies have been initiated of the magnetic structural, electronic and optical properties of materials in the $La_{2-x}Sr_xCuO_4$ family; these compounds have recently attracted broad attention because of the discovery of high temperature superconductivity for $x = 0.15$. Our crystal growing group at MIT has grown the first large single crystals of $La_2CuO_4$ with and without Sr. A variety of novel effects in these crystals have been discovered. First, the nominally pure material orders antiferromagnetically at $130$ K with a remarkably small moment of $0.1\mu_B$. A crystal with Sr content $x = 0.02$ does not appear to order magnetically at all. The low-lying phonon excitations have been studied and were found to have quite conventional behavior, thus supporting arguments that the superconductivity involves a new mechanism. The conductivity in both pure and doped compounds follows the law $\exp(-T_c/T)^{1/4}$ over many decades.

With the assistance of a visiting professor from Tel Aviv last year, much of the behavior of bond-orientationally (BO) ordered phases has been understood. During the past year, further experiments have been carried out on the MIT/IBM beam line at the National Synchrotron Light Source as well as at Stanford Synchrotron Radiation Light. The experiments revealed an unexpected harmonic scaling of the harmonics of the BO order parameter; the nth harmonic scaled as the fundamental raised to the power of $\sigma_n$. Subsequent theoretical analysis, based on the observation that the various harmonics represented the breaking of different symmetries, showed that the different $\sigma_n$ were determined by the crossover behavior from one symmetry to the other. The sequence $(\sigma_n)$ represents an infinite set of independent critical exponents, all of which characterize the phase transition. Those for $n > 3$ had never been measured before. Theory based upon renormalization group calculations predicts $\sigma_n = n + 0.295(n(n-1))$, a result which compares well with the experimental data.

As a result of this work a great deal more is understood about this interesting state of matter which has some of the ordering of a crystalline solid and some of the disorder of a liquid. The results are applicable to any phase transition in which the order parameter has two degrees of freedom and may therefore be represented as a complex number. Examples include a variety of commensurate-incommensurate phase transitions and certain graphite intercalants.

Viscosity, quasielastic lightscattering and neutron scattering measurements have been performed in collaboration with a member of the Department of Nuclear Engineering on a dilute three component microemulsion system consisting of water, hexane and the surfactant didodecyl(dimethyl)-ammonium-bromide. Together these kinds of measurements reveal the structure of the surfactant coated water droplets in the hexane which make up the dilute phase of the microemulsion. The results show that for equal water and surfactant weight fractions the water droplets are spherical with a Gaussian distribution of sizes. When the water to surfacetant weight ratio is increased to 0.6, the droplets become elongated. A model of prolate ellipsoids fits that data well. The change in viscosity with the volume fraction taken up by the droplets supports this interpretation. Further droplet growth appears to take place by two droplets connecting together along the major axis.
These preliminary experiments have shown that a combination of several experimental tools can reveal the microscopic structure of microemulsion phases.

With the publication of the first measurements ever reported of magnetic fields generated by electrochemical reactions of metals in high conductivity solutions, the Specialty Materials Laboratory has fostered a new direction of corrosion research and a new application for superconducting device SQUID technology.

3. Plasma Physics. Versator II is a medium-sized tokamak with primary emphasis on basic investigations of RF plasma heating and current drive. In 1987, construction of a major new 100 kW, 35 GHz electron cyclotron resonance heating (ECRH) experiment was completed. Further experiments will test plasma heating and current-drive processes using a combination of RF power over the lower-hybrid frequency and the electron cyclotron frequency. A second, combined current-drive experiment is in the construction stage, which will use 800 MHz fast lower-hybrid waves in conjunction with 2.45 GHz slow waves. Again, the combination of the two types of waves will provide a test of the theory of RF current drive. This experiment is expected to become operational later in 1987.

In the Alcator C tokamak experiment the following major activities were pursued during the past year:

a. "Sawtooth" suppression experiments in the presence of RF current drive in mostly ohmic-driven plasmas, with the goal of improving the central confinement time. The objective of these experiments is to improve the energy confinement time in conventional tokamak regimes, as well as to find means to achieve steady-state tokamak operation.

b. Ion cyclotron range of frequencies (ICRF) heating experiments at high densities include the novel concept of ion Bernstein wave (IBW) heating, where significant increases in the ion temperature were observed, as well as the more conventional fast-wave heating. The IBW heating resulted in significant improvements of the particle, and possibly energy confinement times even under conditions of edge absorption. Fast-wave ICRF heating experiments concentrated on the hydrogen minority heating technique, in which power is coupled at the fundamental cyclotron resonance to minority (1-10 percent) protons in a deuterium plasma. Experiments were carried out in a density range from $0.5 \times 10^{14}$ to $6.5 \times 10^{14}$ cm$^{-3}$ at powers up to 0.45 MW. The goal of these experiments is to find optimal ways of heating tokamak plasmas at ultra-high densities ($\rho_e > 1 \times 10^{14}$ cm$^{-3}$) in devices such as the planned Alcator C-MOD and the Compact Ignition Tokamak (CIT), and to study the physics of RF heating and tokamak energy transport.

c. Lithium pellet injection experiments were carried out using a pneumatic injector which delivered cubic pellets, 0.7 mm on a side, at velocities up to $10^5$ cm/sec to the center of the tokamak discharge. The principal purpose of these experiments was to investigate the feasibility of using Zeeman polarimetry to measure the current density profile of the plasma. Results employing the Li$^+$ transition at $\lambda = 5485\AA$ were very successful. Fueling and penetration by the lithium pellets were also studied.

Experiments on Alcator C were completed in March, 1987, following nine years of pioneering contributions to the physics of tokamak plasmas. The Alcator C core has been disassembled and moved to Lawrence Livermore National Laboratory where it will be used to investigate electron cyclotron resonance heating of tokamak plasmas by high-power free electron lasers.

Construction of a new experimental tokamak facility called Alcator C-MOD was approved by DOE in April, 1987. Alcator C-MOD will be sited in the east wing of the Nabisco Laboratory and will take about 30 months to build. This advanced high-field tokamak will incorporate a magnetic divertor and plasma shaping capability. Basic equilibrium, stability and confinement properties will be investigated under conditions of intense RF heating (4 - 8 MW) and high toroidal plasma current (3 MA). Projected plasma temperatures and Lawson confinement parameters are in the range of 4-8 KeV and $2 \times 10^{14}$ cm$^{-3}$-sec. Advanced current-drive techniques and methods for impurity control will also be developed on this versatile tokamak facility.

A new Division of Coherent Electromagnetic Wave Generation has been established in the Plasma Fusion Center. The primary objective of this Division is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1 \(\mu\)m to 1 cm range. Particular emphasis is placed on the development of free electron lasers, gyrotrons and novel radiation sources. A second area of research relates to theoretical studies of the basic equilibrium and stability properties of nonneutral plasmas and intense charged particle beams. A third area of research involves
basic theoretical and experimental investigations of laser-pumped, far-infrared molecular gas lasers, including studies of laser tuning and efficiency.

A new experimental concept, Ignitor, developed at MIT and overseas, has become the major national objective of the research program on controlled fusion research. This consists of a compact, high magnetic field experiment, incorporating new technological solutions, that can prove whether a plasma composed of heavy hydrogen isotopes, can reach fusion ignition conditions. Such an experiment can be considered the proof of scientific feasibility of fusion. Achieving ignition conditions has been envisioned as the first step of a large-scale international cooperative effort that has been spurred by the agreement reached on this subject at the Geneva summit between Gorbachev and Reagan.

Nuclear and Particle Physics Division

1. Experimental Heavy-Ion Physics. Nuclei are normally kept apart by strong Coulomb forces. When nuclei collide with sufficient energy to overcome that barrier, a richness of phenomena is observed whose study has given us deep insights into nuclear properties. For almost two decades the Heavy-Ion Group at MIT has carried out these studies in order to investigate the properties of nuclei at the limits of their stability.

The imminent ability of accelerators to produce heavy nuclei with energies of a thousandfold in excess of the Coulomb barrier holds the promise of studying nuclei at the limits of their density and energy. The interaction of extreme relativistic ions with targets as heavy as uranium is expected to produce matter densities and energy densities almost an order of magnitude greater than normal. New phases of nuclear matter may appear. It has been conjectured that in these dense states a plasma may be formed from the quarks which make up the nucleons in the nuclei and the gluons which bind the quarks. The interactions at close quarters may break the bonds which confine the quarks and thus set them free. It is to these studies that the Heavy-Ion Group has now turned its attentions.

The studies of these phenomena will begin with beams of relativistic heavy ions (15 GeV/A silicon) produced at Brookhaven National Laboratory (BNL). Neither the energy nor the mass of these initial beams is expected to be high enough to produce a quark-gluon plasma, but the densities will still be an order of magnitude greater than any hitherto observed under controlled conditions. The objective in the coming years is to eventually reach collision conditions that approximate those conjectured to have occurred in the early stages of the expanding universe.

2. Intermediate Energy Physics. The principal activity in this field is centered at the BLA, which is operated under the joint auspices of LNS and DOE. The Laboratory serves the national community providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aiming at fundamental understanding of the nuclear force. Twenty-two MIT graduate students were associated with the intermediate energy research program during the past year. The intermediate energy research programs of MIT faculty and research staff, both at BLA and at off-campus facilities, are described below.

A large fraction of the faculty and senior research staff participating in intermediate energy nuclear physics at BLA performed a difficult set of experiments on the tritium and ³He nuclei during the previous year. The aim of the program is an extensive and precise characterization of the electromagnetic structure of three-body nuclei. These systems are rather special in permitting a particularly sharp confrontation with theoretical expectations while still possessing structures rich enough so as to bear upon a host of important issues. The technical challenge arose principally from the need to contain a large inventory of radioactive tritium in a geometry appropriate for precision experiments. Analysis of the data has been the main effort of the past year and involves the Ph.D. research of four graduate students. Isoscalar charge and isovector magnetic form factors are in reasonable agreement with current models, whereas the isovector charge and the isoscalar magnetic form factors show significant deviations from models.

Precision electron scattering studies of the structure of more complex nuclei have continued. The magnetization distribution in oxygen-17 has been resolved to an unprecedented short distance scale. Analysis of these results shows the need for large core polarization at intermediate momentum transfers. However, at the larger momentum transfers (>2.5 fm⁻¹) only single neutron behavior is demonstrated with no need for many body currents.
A major effort has been and will continue to be focused on studying nuclear response to large energy transfer. A benchmark coincidence study of protons knocked out of the nucleus by electrons is underway. The goals of the program include understanding single-nucleon motion in the nucleus, modifications of nucleon structure in the medium and contributions to the electromagnetic current arising from the close interaction of two (or more) nucleons. The first results of the measurement program are extremely provocative. For example, a surprisingly large fraction of the nuclear response appears to involve the direct ejection of more than one proton. Further, even qualitative features of the nucleon electromagnetic coupling, such as the ratio of strengths to photons of different polarizations and the variation of coupling strength with momentum transfer, appear to be modified in the nuclear environment. These results are widely held to be associated with nucleon substructure, but a far more extensive experimental characterization is needed for guiding quantitative theoretical approaches.

Direct emission of single protons by intermediate energy photons has been studied. An interesting scaling phenomenon has been found in comparing data for different energies and may provide the clue needed for extracting information about the probability for finding nucleons with very large momenta in the nucleus. This in turn would be very instructive for understanding the short-distance structure of the nucleus. A large effort is underway to clarify this by examining the same process for neutron emission. This is a difficult task in which neutron spectroscopy is achieved by magnetic analysis of recoil protons from np backward scattering. Successful data taking is underway.

A unique test of the unified theory of electromagnetic and weak interactions to be carried out at BLA, is in preparation. The experiment aims to measure the very small asymmetry expected (\(-10^{-6}\)) in elastic scattering of right-and-left-handed electrons from nuclei. A major obstacle for such an experiment is the need to produce a beam of polarized electrons; this has recently been accomplished after a long development program.

Another major experiment in preparation, again involving many of the faculty and senior research staff, aims to measure the monopole and quadrupole charge distributions of the deuteron for the first time. It is perhaps surprising that these fundamental quantities are not individually yet known but, with the completion of ongoing upgrades, the Bates accelerator will be the first with the required combination of energy, intensity, and duty factor to permit the measurement to be made in an interesting regime. There are many theoretical speculations about the short-distance structure of these charge distributions; and the data, which are expected to be taken by the end of 1987, are awaited eagerly.

In August 1986, the results of two reviews of the proposed storage ring upgrade at BLA became available. A scientific review was conducted by the Nuclear Science Advisory Committee of the NSF and of the DOE, and a technical review was carried out by the DOE. The results were both very favorable. The first year of research and development funding for the proposed storage ring has been approved.

Complementary to the Bates experiments are investigations by the MIT Group at other accelerator facilities. The largest program is that examining selected pion-induced reactions at the Los Alamos Meson Physics Facility. This program aims at isolating pion interactions with nucleons and with nucleon clusters in the nuclear medium, particularly in the energy regime corresponding to the lowest excitation of the nucleon. In doing so, one expects to learn how internal nucleon structure affects the strong interaction of baryons. Both pion annihilation and charge-exchange reactions are being examined. The former have proved rather convincing in revealing many-body effects in the annihilation process, a process intimately connected with the origin of the nuclear force. Single and double charge exchange studies are used to isolate the pion interaction with nucleon pairs. Such a unified approach encompassing scattering from and absorption on nucleon clusters is essential for advancing our understanding of strong interaction dynamics.

Another group is collaborating with BNL physicists in a study of hypernuclei. These are nuclei in which one of the nucleons is replaced by a particle carrying strangeness (i.e., one of the light quarks which makes up ordinary matter is replaced by a strange quark). Both \(\Lambda\) and \(\Sigma\)-hypernuclei have been studied, leading to an experimental determination of the interaction strength of strange particles with nuclear matter. Electromagnetic transitions in \(\Lambda\)-hypernuclei are being studied, particularly with a view towards a reliable measurement of the \(\Lambda\) spin-orbit force. In addition, the group continues to investigate new methods for the detection of solar neutrinos.
3. Experimental Particle Physics

a. Accelerator Physics Collaboration (APC) Group. The APC Group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois and the Gran Sasso (GSL) at L'Aquila, Italy.

The Group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics. The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can also make the best search for neutrino oscillations. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

b. Counter Spark Chamber (CSC) Group. The CSC Group has been involved in a FNAL-based program of studying the structure of the nucleon and the structure of the weak interaction using neutrinos as a probe. The major focus has been on the analysis of the data obtained to determine the structure functions of the nucleon, as sensed by the weak neutral current, and to make detailed comparisons of the neutral and charged current interactions with the nucleon. The results obtained are consistent with the predictions based on the Weinberg-Salam-Glashow (W-S-G) weak electromagnetic unification theory and the quark-parton model, and have yielded a new precision value of the weak mixing angle. The Group has continued its neutrino studies with Tevatron II, the FNAL 1000 GeV accelerator. The major objective in the first experiment in this program has been the study of the "like sign" dimuon process, which presently is not understood. One more experimental run will be performed this year, and this will complete the program.

In addition, the Group has recently entered into two other major collaborative programs. (1) The use of \( \nu \) mesons at the Tevatron to study nucleon structure and the mechanisms of particle production. The Group has participated in the construction of a spectrometer to be used in these studies. (2) The use of 50 GeV \( e^+ e^- \) colliding linac beams (Stanford Linear Collider) at the Stanford Linear Accelerator Center (SLAC) to investigate the physics of the intermediate vector boson \( Z^0 \). The Group is now collaborating in the construction of an advanced detector, called the SLAC Large Detector (SLD), which will exploit the new energy region to investigate a number of physics issues. In particular they will search for Higgs particles produced in the decay of the \( Z^0 \). This latter program is the major group effort for the foreseeable future. The detector is now being assembled and the new accelerator is just beginning to function.

c. Lepton Quark Studies (LQS) Group. The LQS Group is also collaborating on the construction of the SLD detector. They are engaged in the development and construction of the Central Drift Chamber for the SLD detector. The Group continues its analysis of the SLAC Hybrid photoproduction experiment. A strong commitment is planned to study the use of the proposed Superconducting Super Collider. In particular, studies of new technologies in detector development are being proposed.

d. Electromagnetic Interactions (EMI) Group. The EMI Group is engaged in two efforts in experimental high energy physics; one at the highest existing electron-positron colliding beam accelerator, PETRA, in Hamburg, Germany, and the other at the 240 GeV electron-positron accelerator, LEP, in Geneva, to be operating in 1990.

The work at LEP: The Group is leading a large construction effort, which involves 350 Ph.D. physicists from 12 nations, to build a large detector to measure photons, electrons, and muons precisely. The experiment is the first large-scale collaboration between physicists from the Soviet Union, the People's Republic of China, and the United States. The construction of this experiment is proceeding according to schedule and will be ready for data-taking by the time of the first LEP beam. The purpose of this experiment is to understand the origin of the masses of elementary particles.

The work at PETRA: After its discovery of gluons, this Group has concentrated on the study of the properties of gluons to increasingly high orders of accuracy. Of particular importance is the Group's recent work on the determination of the second order coupling constant between gluons and quarks, showing that the general theory of strong interactions between quarks and gluons is understood. In addition, they have shown that the expected sixth quark, known as the top quark, is much heavier than previously expected. Their
measurement of direct muon production has yielded a much better understanding of the ways in which different quarks transform themselves into ordinary subatomic particles. Over the past year, the Group has completed the taking of data with a new high resolution vertex chamber to study the lifetimes of new heavy particles, and this program is now complete.

e. Proton-Antiproton Collision Group. This Group is an official member of the UAI collaboration at CERN. After the discovery of the W and Z particles in 1982-83, a large amount of data was collected. This Group leads the main analysis effort in search for the top quark. Other analysis activities include the further study of properties of the Z and W, the search for new leptons with masses above 41 GeV/c², the study of monojets, the search for supersymmetric particles, and the mixing of B⁰ and anti-B mesons. The Group is planning to expand its emulator system for analysis by an order of magnitude to accommodate much greater data yields anticipated in upcoming UAI experiments. The Group also plays a major role in the construction of position detectors for these future experiments.

Theoretical Division

1. Particle Theory. The "standard theories" of the interaction of quarks and leptons through gauge fields are quantum chromodynamics (QCD) for the strong interactions, the W-S-G theory for the electromagnetic and weak interactions and general relativity for gravitational interactions. They are powerful and in complete agreement with experiment, but they contain no answers to the fundamental question, why this particular hierarchy of particles and interactions? Clues can be sought within the structure of quantum field theory itself. In this direction the Particle Theory Group has continued to explore the nature of anomalous gauge theories in which the quantization procedure destroys the classical symmetries. The theory of super-strings endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is totally inaccessible to experiment, this theory makes great use of internal consistency requirements. Members of the Group have discovered an elegant geometrical formulation in which field equations appear from the requirement that the curvature of an infinite-dimensional complex space is zero. The Group has also made new discoveries in the algebraic approach to the construction of string field theory.

Other members of the Group have studied the physics which will become accessible with the next generation of experiments, up to the Superconducting Super Collider. It has been found that our present knowledge already severely restricts models in which quarks and leptons would themselves appear composite in these experiments. Among problems in the application of the standard theory studied by the Group are the strange quark content of the proton and the effects of exchange of quarks between nucleons inside a nucleus.

The attempt to understand the beginning of the universe provides a drastic test of our theoretical assumptions. Members of the Group have shown, using classical general relativity, that it is in principle impossible to create a whole new inflationary universe "in the laboratory", i.e., out of a concentration of energy in a small region. They will next study whether quantum fluctuations change this conclusion. Two spectacular astronomical events, the gamma-ray burst of March 5, 1979, and the supernova of February 23, 1987, have stimulated research in the Group. A scenario for the burst, making use of the Group's ideas on strange matter has been proposed. The information from the arrival times of the neutrinos from the supernova was used to place new limits on neutrino interactions.

2. Nuclear Theory. Nuclear theorists at MIT address a broad range of problems in contemporary nuclear physics. The research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role. Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

The role of quark substructure and QCD effects in nuclei is a growing focus of research, because of its fundamental significance and the unique resources in the Center for Theoretical Physics at the interface between nuclear and particle physics. One approach is to solve QCD numerically on a lattice, and efforts in lattice gauge theory range from technical developments to the study of magnetic monopoles and the properties of QCD at high temperature. A long-term objective is to calculate the nucleon on a lattice in order to test and distinguish between the various quark, bag and soliton models. The general theoretical problem of how to formulate effective operators in hadronic degrees of freedom relevant to conventional low energy nuclear physics is being studied in the context of a
non-relativistic confining quark model. The bag model, which economically enforces the confinement aspects of QCD, is being used to explore the possibility of observing multiquark resonances in hadron scattering. A complementary description motivated by the large N limit of QCD, in which the only relevant degrees of freedom are meson fields, is being explored by studies of chiral and soliton models.

Relativistic heavy ion collisions comprise another area of growing activity, motivated by the unique opportunity they provide for fundamental exploration of new regimes of matter, new and imminent experimental data, and the major new experimental effort in this field at MIT. A flux tube model has been developed in which two interpenetrating nuclei become color charged and generate a strong confined color field which creates quark-antiquark pairs. In this model, the hydrodynamic evolution of the plasma, the non-abelian classical evolution of the color fields, deflagration of the flux tube, and fragmentation have been investigated. Another major focus has been the study of possible experimental signatures of the formation of quark-gluon plasma. The results of this study, that strangeness production is a poor indication of plasma formation and that suppression of $J - \Psi$ production by screening in the plasma is a promising possibility, are of great importance for the planning of new detectors and experiments.

Problems in the quantum theory of collective motion ranging from nuclear fission to the quantization of large amplitude vibrations involve periodic solutions to time dependent mean-field theory. Research has focused on understanding the nature of periodic solutions to multidimensional classical systems and field theories and calculating periodic solutions for physical processes. The stochastic solution of many-body problems has proven valuable in a variety of applications, in addition to lattice gauge theory, ranging from the exact solution of non-relativistic models with static two-body interactions and studies of relativistic meson-nucleon field theory to calculation of the thermodynamic properties of quantum spin systems. An example of the strong interplay between many-body theory and field theory is the exploitation of the analogy between "deformed" gluon states in QCD and deformed nuclei.

Electromagnetic interactions are of great theoretical interest, because of the unique precision of electromagnetic probes. Important new questions involving coincidence experiments and polarization observables arise from the Bates Laboratory program and its upgrade. Much of the current work addresses coincidence experiments, ranging from fundamental studies of the reaction mechanism in proton knockout experiments, to explanations of how spin observables can be exploited to reveal new features of nuclear structure. Hadron scattering provides insight complementary to that obtained from electromagnetic probes. The role of intermediate isobars in medium energy reactions has been a central focus in intermediate energy research at MIT, and current investigations address the contribution of delta-nucleon collisions in ($\pi$, $\pi$N) reactions and study the effects of intermediate isobar channels in nucleon-nucleon scattering.

JEROME I. FRIEDMAN
The William H. Bates Linear Accelerator Center, located in Middleton, Massachusetts and operated under the joint auspices of the MIT Laboratory for Nuclear Science and the US Department of Energy, serves as the national user facility for intermediate energy electro-nuclear physics. The Laboratory supplies high intensity (average current ~50 µAmps), high quality electron and photon beams with energies up to 850 MeV. A spectrometer of unmatched resolution supports a program of precision measurements of nuclear electromagnetic charge, current and magnetization distributions. A second experimental area is equipped to support a vigorous program of photoreaction studies, with protons, neutrons, charged and neutral mesons, and photons detected with good resolution. Further, the electron beam duty factor of ~ one percent, together with a unique set of magnetic spectrometers, permits an exploratory program of coincidence studies. This program has been particularly compelling in pointing towards a major facility upgrade needed for effectively pursuing new directions in the field; this upgrade will be described below. Beam time is assigned to experimental proposals on the basis of scientific merit with the advice of a Program Advisory Committee with international representation. Roughly one-third of the beam time is presently assigned to MIT faculty and staff. There are currently about 200 active participants in the research program, drawn from over 50 universities and research laboratories; this substantial number reflects the unique capabilities developed at Bates. The MIT-Bates intermediate energy research program has been exceptionally effective in graduate education, producing between five and ten percent of the nation's Ph.D.'s in nuclear physics during the last several years. A recent graduate, Charles Hyde-Wright, has been named a Presidential Young Investigator.

In 1986, the major effort at Bates was an electron scattering study of the three-body nuclei, tritium and helium-3. The experiment was led by scientists from MIT and Virginia, with participants from six other universities deeply involved. The three-body nuclei are particularly important because they are simple enough to permit quantitative confrontation with theory and yet are rich enough to display many of the phenomena of greatest current interest. The major obstacle lies in containing a large inventory of radioactive tritium (140,000 curies) in a configuration suitable for precision experiments. The data analysis is now almost complete. The integrated strength of the Coulomb response function demonstrated clearly the important role played by strong short-range repulsive correlations in the nucleus. This repulsion is now widely accepted as originating in the quark substructure of the nucleon itself. Surprisingly, however, the distribution of strength, which reflects the dynamics at high frequency, is not yet understood. Further, the response to magnetic probes confirms the important role played in the nucleus by additional hadronic degrees of freedom, namely, mesons and nucleon excitations.

The Laboratory is committed to pursuing other ambitious studies of few-body nuclei. These are of fundamental interest in our attempts to understand strong interaction dynamics at distance scales smaller than the size of the nucleon. Specifically, an extremely complex (double-scattering) experiment is now underway to provide the first measurement of the monopole and quadrupole charge distributions of the deuteron in a theoretically interesting regime. Several upgrades and equipment fabrications have been needed to give us this unique capability. We expect to complete this experiment in Fiscal Year 1988. In addition, studies of deuteron breakup under extreme conditions (i.e., the proton and neutron unbound but moving off together) will be extended to very small distances. This process has provided the most convincing and quantitative evidence for the role of pions in the nuclear ground state. To push this understanding to the much shorter distance scale of considerable current interest, we will need to develop the capability for measuring cross sections two orders of magnitude smaller than those which have been measured so far. Both of these deuteron experiments involve large collaborations and several institutions.

The research program in another experimental area centers on studies of nuclear response to large energy transfer, i.e., energies large enough to produce mesons and to produce internal excitation of the nucleon. For example, the only measurements of elastic photon scattering from a nucleus above the threshold for pion production have been performed at Bates by a BU-MIT group. These data have complemented pion scattering studies from other laboratories in yielding a quantitative characterization of the nuclear interactions of excited nucleons.

An important exploratory coincidence program, in which high energy protons knocked out of the nucleus are measured simultaneously with the scattered electron, is being pursued by scientists from MIT, William and Mary, Maryland, Argonne, California State and other institutions. These have been benchmark studies pointing to an understanding of how the nucleus absorbs large momentum and energy transfer. Recent results include a direct measure of the mean free path for nucleon propagation in the nuclear medium and insight into the role of multinucleon currents at high frequency. The much more extensive experimental study demanded by these results argues strongly for the proposed Bates upgrade to high duty factor operation.
An MIT-Glasgow-South Carolina collaboration has found an interesting scaling behavior in the ejection of single protons by intermediate energy photons. This result holds promise for shedding light on the probability for nucleons to have very large momentum inside the nucleus. This elusive quantity is of great interest because of its sensitivity to the short-distance structure of nuclei. An MIT-led group has examined the analogous process for neutron ejection. This challenging experiment was the first of its kind and should tightly constrain interpretation of this important process. The time-consuming data analysis needed for this experiment is underway.

A collaboration led by Yale, MIT and Syracuse continues to pursue an experiment aimed at providing a unique test of the unified theory of electromagnetic and weak interactions. The experiment will measure the very small asymmetry expected \((-10^{-6})\) in the elastic scattering of electrons with spin aligned parallel or antiparallel to the beam direction. Substantial progress has been made recently, specifically, in accelerating a high intensity \((\sim 50\mu\text{Amp})\), highly polarized \((\sim 38\text{ per cent})\) beam of reasonable lifetime. The collaboration is now focussing on the source of potential systematic errors which could mask the very small anticipated asymmetry. Following this experiment, we anticipate in Fiscal Year 1989 a major program of strong interaction studies with the polarized beam. This will be a unique program, essentially using spin observables for the first time in electronuclear physics.

Substantial progress was made in the last year on a variety of important Laboratory upgrades. The polarized beam was already mentioned. The maximum electron energy was raised to about 850 MeV with the ongoing upgrade of the RF system; we hope to reach 1000 MeV in the Fall of 1987. In the experimental area, a neutron spectrometer was made operational, cryogenic targets have been constructed, a deuteron transport channel was built, and an Alberta polarimeter was installed. These capabilities have made qualitatively new research opportunities available. We are now examining designs for constructing prototype out-of-plane spectrometers; these will be very important in exploiting future CW capabilities.

The Laboratory has continued to develop plans for a major upgrade. The essential new capabilities are continuous beams and the provision of polarized targets. The former are needed to advance the coincidence program which is proving so interesting even with our limited duty factor. The latter is needed for full exploitation of spin observables, thereby realizing the full power of the electromagnetic probe. We have submitted a proposal to the Department of Energy for construction of a Pulse Stretcher Ring - Internal Target Hall complex. This would provide both capabilities at a total cost of about $25 million (Fiscal Year 1987 dollars). The scientific merit of the proposal was evaluated, in competition with other proposals, by the Nuclear Science Advisory Committee; their August 1986 report described our project as "a singularly compelling upgrade". We then had a detailed technical/cost/schedule/management review conducted by the Department of Energy; this report concluded that the project is ready to start. In May 1987, the project scope and cost was firmly established in a Department of Energy Validation Review. Discussions about possible Fiscal Year 1989 construction funding are continuing.

ERNEST J. MONIZ
The Cell Culture Center at MIT was established in 1974 to serve as a facility and resource for all biologists throughout the United States. The Center is headed by Professor Phillip A. Sharp, Principal Investigator, and Donald J. Giard, Director. The mission of the Center is to produce cells and cell products on large scale in order to allow scientists to conduct basic research that could not be accomplished with the materials and resources in the investigator's own laboratory. The Center is working directly with individual scientists on basic research problems, and in addition, is conducting an active program in the development of new technology for large scale animal cell production.

Production

During the period July 1, 1986 to June 30, 1987, the Cell Culture Center provided animal cells and cell products to 51 research groups throughout the United States. Cells were produced in a variety of ways including roller bottles, suspension cultures and microcarrier cultures. During this period more than $10^3$ cells were produced as the demand for cells continued to increase. Examples of projects completed during the past year include:

- 340 roller bottles of chicken embryo fibroblasts and BHK-21 cells for Harvard University, Cambridge, MA.
- 310 liters of HPB-ALL cells for Beth Israel Hospital, Boston, MA.
- 56 liters of RFP/EC cells in microcarrier culture for MIT, Cambridge, MA.
- 140 liters of Drosophila Kc cells for MIT, Cambridge, MA.
- 100 liters of TA-3 cells for Washington University School of Medicine, St. Louis, MO.
- 115 liters of lymphoblastoid cells for Dana Farber Cancer Institute, Boston, MA.
- 100 liters of HeLa S-3 cells for Johns Hopkins University, Baltimore, MD.

Cell Sorter Laboratory

The Cell Sorter Laboratory was established in 1980 as a discrete element of the Cell Culture Center, to serve as a local facility and resource for all biologists primarily in the Northeastern United States. Its purpose is to provide analysis and separation of cells and other small biological particles for qualified researchers who do not have sufficient resources and equipment in their own laboratories using this type of specialized technique. During the past year a total of 56 research groups utilized the service of the Cell Sorter Laboratory. During the past year, Juanita Torres, the cell sorter operator, took a new position and was replaced by Vincent Falco from Sloan Kettering Institute. During the coming year, the System 60H Cytofluorograph will be updated to state of the art condition, and additional instrumentation will be added to further increase the laboratories capabilities.

Research and Development

Research at the Center over the past year has focused on the following areas:

1) Development of Mathematical Descriptions of Mammalian Cell Culture Kinetics for the Optimization of Fed-Batch Bioreactors. The emphasis on this project has been on the development of mathematical equations designed to optimize both the growth rate and specific antibody productivity of a hybridoma cell line. Implementation of one optimal control policy resulted in cell and antibody levels twice that which is typically obtained in batch cultures.

2) Effect of Heat-inactivation of Serum on the Attachment of Animal Cells in Culture. This research has demonstrated that routine heat-treatment of bovine sera reduces its capacity to promote cell attachment when cells are subjected to mild shear. Since transformed cells appear to be affected to a greater degree than normal cells, one possible application of this phenomenon is the development of a unique method for separation of heterogeneous populations of cells.

3) Development of a Hollow Fiber Reactor Design for Production of Animal Cells and Their Products. The focus of this research is to develop an alternative hollow fiber reactor design that is easily scalable and in which oxygen limitation is reduced. Several prototypes have been constructed and are currently being evaluated.
The Center for Cancer Research was established in 1973 to study fundamental biological processes related to the human disease of cancer. Research programs in three major areas, immunology, cell biology, and oncogenes and mammalian genetics, are being actively pursued by 11 faculty members and their laboratories. The Center is currently the research home of 150 people including faculty, research staff, postdoctoral fellows/associates, visiting scientists, and graduate and undergraduate students. The support for the Center has remained strong with a 20% increase in total research volume during the past year. Two active searches for new faculty are in progress which would bring the total to 13 members. The only change in academic appointments during the past year was the promotion of Dr. David Raulet to Associate Professor in the Department of Biology.

Professor Raulet is a promising young immunologist with an interest in the development of the immune system in mammals.

Several advances in research were made during the past year in the Center. The immunology group has continued to analyze the properties of T cells. These cells recognize foreign antigens on the surface of another cell and then release compounds that kill the second cell. Professors Tonegawa and Raulet have continued their genetic analysis of the receptors on the surface of T cells that recognize the foreign antigens. In particular, they have determined the genetic diversity of the gamma receptor genes, a new class of T-cell receptors discovered by Professor Tonegawa. T cells must be activated to be able to kill target cells. Professor Raulet has found that a previously identified interferon (B) has critical T-cell activating properties. Professor Eisen discovered a few years ago that a particular type of protein degrading enzyme, serine esterase, was secreted by T cells during the killing of other cells. A gene encoding this protease has been isolated and studied.

Mammalian cells sense their environment through transmembrane receptor proteins. Changes in the ability to recognize the appropriate environment is a common feature of tumor cells. Professor Hynes has recently isolated genes for one of the major types of transmembrane receptor proteins. This receptor forms a bridge between the extracellular matrix composed of fibronec tin and the intracellular skeleton composed of actin. A puzzling aspect of human cancers is their ability to become resistant to a broad spectrum of toxic compounds. Professor Housman's laboratory has shown that this resistance is due to the amplification of the copies per cell of a gene encoding a cell surface protein, the multidrug resistance gene. Increased levels of this protein probably confers resistance by transporting the different types of drugs from the cell.

The research and academic activities of the Center's faculty members have been recognized by a number of awards and prizes. We are very proud that Mr. Antoine Firmenich, one of our undergraduate students in Professor Eisen's laboratory, received the 1987 Assinari Prize for excellence in research in biology by an undergraduate. At the faculty level, Professor Raulet received the Cancer Research Institute Investigator Award (1986) and the Robert A. Swanson Assistant Professorship of Life Sciences (1986). Professor Brent Cochran received the nationally competitive Searle Scholarship (1986). Professor Tonegawa received the Robert Koch Prize (1986) and an Honorary Degree from Northwestern University for his research in immunology (1987). Professor Sharp received the Gairdner Foundation International Award (1986), the New York Academy of Sciences Award in Biological and Medical Sciences (1986), and was nominated to Councilor of the National Academy of Sciences (1986).

A large number of postdoctoral fellows/associates, research associates and visiting scientists contributed invaluably to research in the Center. Occasionally, an individual can be singled out for special recognition. As an example, Dr. Maria M. Konarska received a nationally competitive grant from the Lucille P. Markey Charitable Trust (1987). There are in total 32 scientists at the postdoctoral level supported by competitive fellowships. The Center has also benefited from a number of faculty-rank visitors: Professor Michael Sela of the Weizmann Institute, Israel; Professor Harald von Boehmer of the Basel Institute of Immunology, Switzerland; Professor Richard Condit of the University of Buffalo; and Associate Professor Andrei Augustin of the University of Colorado Medical Center. The Center was also host to seven medical fellows: Drs. Mark Iannini, Margaret Liu, both from Massachusetts General Hospital; Mark Pasternack and Judah Weinberger from Harvard Medical School; James Croop from the Dana-Farber Cancer Research Institute and Children's Hospital; Jack Hensold from Beth Israel Hospital; and Jack Lawler from St. Elizabeth's Hospital.

PHILLIP A. SHARP
The Center for Space Research (CSR) conducts an active program of research in astronomy, space science, and technology, with emphasis on experimental and theoretical investigations in support of various National Aeronautical and Space Administration (NASA) flight missions. Although the primary source of support comes from NASA, a significant fraction of the research program is sponsored by the National Science Foundation (NSF) and the Department of Defense (DOD). Specific areas of research include gravity-wave, X-ray, optical, and radio astronomy; theoretical and experimental space plasma physics; planetary surfaces and atmospheres; and the life sciences. The current and near-future NASA flight program contains several missions in which MIT and CSR are heavily involved: the Voyager-2 mission to the outer planets, the Magellan Venus Radar Mapper (MGN), the Cosmic Background Explorer (COBE), the Advanced X-ray Astrophysics Facility (AXAF), the X-ray Timing Explorer (XTE), the Space Transportation System (Shuttle) Spacelab series, and an investigation of Earth's plasma environment as part of the International Solar Terrestrial Physics Program (ISTP). CSR also supports a program of theoretical astrophysics and of optical observations carried out at the McGraw-Hill Observatory. An overview of CSR activities during the past year follows.

RESEARCH IN X-RAY ASTRONOMY

Analysis of Data from Satellite X-ray Observatories. The only satellite X-ray observatory currently operating is the Japanese "GINGA" mission which is not yet available for foreign guest usage. Thus, in the present moribund state of US space astronomy, cosmic X-ray phenomena can only be studied using data from the archives of past US and European missions. The MIT X-ray group has charge of several of the US archives with ready access to the others, and has thus been able to remain active in the field while preparing for the next generation of space missions to be launched in the 1990's.

Professor Hale Bradt and Dr. Ronald Remillard are tracking down and identifying by optical observation the X-ray sources whose positions were measured with high precision in past spacecraft flights. Professor Claude Canizares and his associates are extending their investigations of the high-resolution X-ray spectra of supernova remnants and X-ray galaxies, while conducting correlative studies of accretion flows in several of the X-ray galaxies. Professor Walter Lewin and his collaborators at MIT and abroad are investigating the nature of low-mass binary X-ray sources by analysis of the quasi-periodic oscillations and bursts seen in their X-ray emission, using data from the European X-ray Observatory Satellite (EXOSAT). Professor George Clark and his students are studying the structure of stellar atmospheres through analysis of the occultations of eclipsing binary X-ray sources.

Advanced X-ray Astrophysics Facility (AXAF). Professor Canizares and his group have continued the definition study of instrumentation for the High-Resolution Spectroscopy experiment planned for AXAF. The investigation uses two instruments: an X-ray transmission grating and a Bragg crystal spectrometer. Initial versions of the gratings have been successfully fabricated in collaboration with Professor Henry Smith (EECS) and are being tested in a facility within CSR. A number of candidate Bragg crystals have also been tested for reflectivity and spectral resolving power.

During the past year, the AXAF Charge-Coupled Device (CCD) Imaging Spectrometer experiment (MIT's second AXAF entry) entered the detailed design and definition phase under the leadership of Dr. George Ricker as the MIT lead co-investigator. While the Principal Investigator (Professor Gordon Garmire) is at Pennsylvania State University, CSR has overall management responsibility for this experiment.

X-ray Timing Explorer (XTE). This effort represents a relatively inexpensive NASA X-ray astronomy satellite program that has been proposed for launch in the mid1990's. MIT is responsible for one of the three experiments that have been selected, namely to study the time variability of celestial X-ray sources at time scales ranging from milliseconds to years. A group under Professor Bradt is involved in mission design and in developing the instrumentation required. As part of this program, CSR is carrying out laboratory studies of positron-sensitive detectors for the Scanning Shadow Camera, which serves as an all-sky X-ray monitor.

McGraw-Hill Observatory. The McGraw-Hill Observatory, located on Kitt Peak near Tucson, Arizona, is operated jointly by MIT (CSR), the University of Michigan and Dartmouth College. It contains a 1.3m-dia telescope that has been available for some years, as well as a recently completed 2.4m-dia instrument that is now fully operational.

Some highlights of work carried out at the McGraw-Hill facility include: the discovery by Drs. Jeffrey McClintock...
 Smithsonian Astrophysical Observatory) and Remillard of one of the best current candidates for a "black hole" in a binary star system; searches by Drs. Ricker and Roland Vanderspek for optical counterparts to the gamma-ray bursters; studies by Professor David Jewitt (EAPS) of the light scattered around Comet Halley; examination of a bright, highly variable, quasar-like object by Professor Bradt and Drs. Remillard and McClintock; measurements of the structures of planetary rings by Professor James Elliot and Dr. Edward Dunham (EAPS); images of ripples in the distribution of light over elliptical galaxies made by Professor Clark; and searches for optical counterparts to radio sources by Professor Bernard Burke.

Explosive Transient Camera (ETC). This facility, colocated with the McGraw-Hill Observatory on Kitt Peak, is designed to search the entire night sky for, and detect, brief flashes of light suspected to be emitted concurrently with high energy gamma-ray burst events. Fully automated operation began in May of this year under the supervision of Drs. Ricker and Vanderspek. Receiving particular attention is the source GB790107, a recently discovered recurrent gamma-ray burster that has produced over 100 brief bursts of radiation above 20 kev in energy over the past 8 years.

RESEARCH IN SPACE PLASMA PHYSICS

Interplanetary and Magnetospheric Plasmas. Currently, the space plasma group, headed by Professors John Belcher and Herbert Bridge and Dr. Alan Lazarus, is involved in the analysis of data received from the Earth-orbiting IMP-8 spacecraft and from the Voyager-2 interplanetary probe that encountered Uranus in early 1986. The group is also entering an intensive planning phase looking toward Voyager observations of Neptune in August 1989, as well as the design of the subsequent interstellar phase of that mission. Emphasis is being placed on studies of the solar wind in the distant heliosphere, in particular, on how it varies over the solar cycle and on how it affects the solar-cycle modulation of galactic cosmic rays. Work also continues on data obtained during the encounter of the European Giotto spacecraft with Halley's comet in 1986, both concerning the composition of the cometary material and the interaction of that material with the solar wind.

CSR anticipates approval in the near future of the WIND spacecraft, an important component of NASA's new Global Geoscience Program (a part of ISTP). The MIT group is scheduled to construct a significant portion of the instrumentation carried on this spacecraft and will have access to the data provided by other components of this program.

Theoretical Geoplasma Research. During 1986, funding was received from the Air Force Office of Sponsored Research under its University Research Initiative for a Center of Excellence in Theoretical Geoplasma Research under the leadership of Dr. Tom Chang, with participation by Professors Belcher and Stanley Olbert and Drs. Geoffrey Chew, Alan Barnett and David Tetreault. This structure, contained within CSR, is designed to foster theoretical research on plasmas, emphasizing the terrestrial ionosphere and magnetosphere. A number of prominent international scientists, as well as postdoctoral research fellows, are being invited to spend time at MIT and to participate in a variety of workshops and symposia organized under this program.

PLANETARY STUDIES

Magellan Venus Radar Mapper Mission (MGN). This mission, designed to map the entire surface of Venus using synthetic aperture radar (SAR) techniques at a resolution approaching 100m, is now planned for launch in April of 1989. Professor Gordon Pettengill is the Principal Investigator for the radar portion of this mission, with support from Professor Sean Solomon (EAPS) and Drs. Joseph Binsack and Peter Ford. Although the SAR data reduction and image production will be carried out at NASA's Jet Propulsion Laboratory, CSR has responsibility for analyzing the ancillary altimetric and radiometric data and presenting the results as images.

RADIO ASTRONOMY

Very-Large-Array (VLA) and Very-Long-Baseline-Interferometer (VLBI) Observations. Professor Bernard Burke and his graduate students, in collaboration with colleagues from Princeton and Cal Tech, have discovered a strong new candidate (Q0023+171) and six promising runners-up that may be gravitationally lensed quasars. In the search process, over 4000 VLA radio maps were prepared.

Working with Professor Burke, Dr. Vivek Dhawan has successfully synthesized a 7-mm VLBI map of the radio source 3C84 at an angular resolution of 140 micro-arc-seconds that provides the most detailed map ever made of this unusual object and has established this wavelength as accessible to standard VLBI observing techniques.

Professor Burke continues as US Principal Investigator of the joint US-European project to establish a VLBI station in Earth orbit (known as QUASAT), now envisaged for realization in the mid 1990's.
RELATIVISTIC GRAVITATIONAL ASTROPHYSICS

Search for Gravitational Radiation. This project, involving Professor Rainer Weiss, Dr. Peter Saulson, and their associates, is well along with the development of a new 5m-long laser interferometric gravitational wave antenna. This prototype, which will test improved detector techniques and also serve as a useful research facility in its own right, will be the last undertaken at MIT prior to construction of the full-scale 4km-long gravitational antenna facilities in Maine and California. Further progress has been made in developing high-power, output-quiet, and frequency-stable lasers, as well as in enhancing the low-frequency seismic isolation provided by the suspension systems.

Cosmology Research. There are several projects underway in this area at present under the leadership of Professor Stephan Meyer and Dr. Edward Cheng: balloon-borne surveys of the sky at centimeter, millimeter, and submillimeter radio wavelengths to search for large-scale anisotropies in the natural cosmic background radiation and to identify possible contamination of the intrinsic distribution introduced by interstellar dust; and participation in the COBE spacecraft mission (scheduled for launch in 1989) to observe the cosmic background radiation from Earth orbit using a variety of instruments sensitive to the electromagnetic spectrum lying between 1cm and 200 μm wavelengths.

Non-linear Dynamics. Dr. Paul Linsay continues his research in non-linear dynamics under a three-year grant from the Office of Naval Research. Studies have been directed towards understanding the transition, undergone in some non-linear electronic systems, from quasi-periodicity (i.e. simultaneous oscillations at several non-harmonic frequencies) to chaos. His group has succeeded in constructing several circuits that demonstrate these transitions, as well as in defining their basic operating domains.

AEROSPACE PHYSIOLOGY

Experiments on human adaptation to weightlessness continue in the Man Vehicle Laboratory (MVL), under the direction of Professor Laurence Young and Dr. Charles Oman (who will be serving as Acting Director of the Laboratory during Professor Young's sabbatical absence in academic year 1987/1988). The research has focused on understanding changes in the visual-vestibular function, spatial orientation, flight simulation posture control, and the origins of space motion sickness. The latter is now recognized as a significant operational concern on shuttle, space station, and manned DOD missions. The stand-down from flight activity resulting from the Challenger accident has provided an opportunity for further data analysis and modification of hardware and crew procedures prior to the third mission in the Spacelab series: SLS-1, now scheduled for 1990.

A vigorous program of ground-based research includes studies of the visual-vestibular interaction using the MVL linear acceleration sled; a “telescience” experiment aimed at defining voice, video, and data communications required for the space station; studies of physiologic changes that accompany the onset of motion sickness; and an evaluation of the utility of a rotating bed centrifuge in combating the zero-gravity deconditioning that occurs during long duration space missions. In a different area, Professor Steven Bussolari has served as director of flight operations for the Daedalus Project, an attempt to fly a man-powered aircraft from Crete to the Greek mainland.

GORDON H. PETTENGILL
The Experimental Study Group (ESG) finished its eighteenth year of alternative academic instruction at the Massachusetts Institute of Technology with increased activity in experimental education, including the development of new laboratory experiences for first year students in chemistry and physics. We are pleased to be able to provide an environment in which innovative ideas can grow and will be continuing such efforts in conjunction with the curricular reforms currently underway at MIT.

STUDENT STATISTICS

ESG enrolled 44 new freshmen, 11 sophomore transfer students, and 22 ESG upperclassmen for one or more terms this year. Thirty-five percent of the entering first year students were women, 18 percent were international students, and seven percent were minority students. This year's students were a diverse group, not only because of the high number of international students but also because of the range in ages and backgrounds of our students. Thirteen percent were over 21 years of age and several were in their late thirties: eighteen percent had been out working or were enrolled in another college or university before coming to MIT. One of our freshmen came back to university after twenty years at a successful business career and completed 84 units during his first term, much of it learned on his own before he came here.

The 39 sophomores currently registered at MIT who had been in ESG as freshmen achieved a median grade point of 4.2, a figure which is higher than the corresponding figures for the entire MIT sophomore class for the sixth consecutive year. Thirty-eight percent of our sophomores are majoring in the sciences and 51 percent in engineering, compared to respective figures of 22 percent and 64 percent for the MIT sophomore class as a whole. These figures have remained relatively constant over the past five years, indicating both a superior academic performance by ESG students in their second year and also a stronger inclination to major in the sciences. Most of the upperclassmen enrolled in ESG took only one subject in ESG, primarily in the humanities and social sciences. The most common reason given for taking a subject in ESG was that it was not given in the regular curriculum.

STAFF AND FACULTY

Professor J. Kim Vandiver, Director of ESG, and Holly Sweet, Associate Director, oversaw the administration of the program in consultation with the ESG Advisory Committee. The Committee is composed of representatives from the MIT Faculty in the fields of mathematics (Professor David Anick), history (Professor Arthur Kaledin), physics (Professor Lee Grodzins), chemistry (Professor Alan Davison, also Chairman of the Committee), and the Dean of the School of Science, Professor Gene Brown. Along with their ESG administrative roles, Professor Vandiver served in his second year as Associate Chairman of the MIT Faculty, and Ms. Sweet continued her appointment as a Lecturer in the School of Science. Both Professors Vandiver and Davison won awards from the Graduate Student Council for excellence in teaching this year.

The mathematics staff included two newcomers to the ESG community, Dr. David Witte, a Moore instructor in the Department of Mathematics at MIT, and graduate student Henry Sadofsky. The physics staff was composed of Professor John King (who specialized in rehabilitating the ESG Physics Laboratory), Professor Emeritus Robert Halfman (who has continued to tutor at ESG since his retirement from the Institute in 1984), graduate student James Mahoney (who was a freshman in ESG ten years ago), and Dr. Peter Dourmashkin and Craig Watkins who ran an experimental physics laboratory for credit during the Independent Activities Period (IAP) in January. Almost all of our first year students took both their math and physics subjects in ESG.

The chemistry staff included two undergraduate students, Marya Lieberman '89 and Seth Brown '88, now in his second year of teaching at ESG. They taught recitation sections in 5.11 Principles of Chemical Science and 5.12 Organic Chemistry to 20 ESG students. Based on student performance and end of term evaluations, their teaching has proved to be very successful. The humanities staff for the year included Fanny Howe (Writing), Holly Sweet (Psychology), and graduate student Lee Perlman (Political Science). In the fall term Professor Gary Marx joined ESG to teach a course on surveillance and society, and Visiting Professor George Siegel gave a seminar on Russian literature. In the spring term Deborah Pekala Wilbert '83 taught Writing Workshop which has been offered each year in ESG since the program began in 1969. Sixty-three percent of our first year students took at least one humanities subject in ESG this year.
Twenty-nine ESG upperclassmen and alumni assisted the ESG staff in tutoring freshmen and sophomores, mostly in introductory subjects in math and physics. We commend our tutors both for their academic excellence (they earned a median grade point of 4.6 as of May 1987) and for their dedicated teaching at ESG which has allowed us to provide such a favorable staff/student ratio.

ACADEMIC DEVELOPMENTS

The theme of this year has been the increased export of ESG ideas and style of teaching to the regular curriculum. Discussions last year which focused on the lack of laboratory opportunities for freshmen in chemistry resulted in the creation of a nine unit undergraduate seminar in chemistry (5S09 Chemistry Demystified: A Laboratory for Beginners) which was designed and taught by three ESG undergraduates. Mr. Brown, Ms. Lieberman, and Julia Hsieh '89 earned a William L. Stewart award in May for implementing this unique laboratory. As a result of extensive meetings with the other two freshman alternative programs at MIT about the need for more practical experience for freshmen, several hands-on projects for credit were offered by the freshman programs during IAP. In addition to courses on journalism and car safety sponsored by the Integrated Studies Program, Dr. Dourmashkin and Mr. Watkins taught a six unit subject on the physics of the bicycle wheel.

Several undergraduate seminars (created and taught by ESG staff members) which had been previously offered only within ESG were opened to students from the regular curriculum this year. Ms. Sweet and Mr. Perlman taught SEM051 Sex Roles and Androgyny to a group of 14 ESG and regular curriculum students. Dr. Dourmashkin, supported by funding from the School of Engineering, taught SEM056 Engineering and Science in the 80's: A Personal Look to students in the regular curriculum, a seminar which had first been offered in ESG in the spring of 1985.

Students in ESG have traditionally been interested in the humanities and social sciences, so it came as no surprise that they were represented in disproportionally high numbers in Institute discussions concerning reforming the requirements in this area which were held in the spring. Three of our students won writing awards and music scholarships at MIT this year, and two of our upperclassmen were selected to be Burchard Scholars. The ESG community voted to use funds donated to ESG by the parents of a recently deceased ESG alumnus to establish an annual literary magazine. The first edition of "Songs of Mind," dedicated to the memory of David Miller '79 who taught Writing Workshop at ESG from 1977 to 1979, will be published this coming summer.

The ESG community looks forward to participating actively in exploring new possibilities in undergraduate education, particularly in the areas of revising the core science requirements, creating new laboratory opportunities, and increasing the visibility of humanities at MIT. Since our students are one of our greatest sources of creativity, we welcome and encourage their participation in this process.

HOLLY B. SWEET
J. KIM VANDIVER
The George Russell Harrison Spectroscopy Laboratory is engaged in research in the field of modern optics and spectroscopy for the purpose of furthering fundamental knowledge of atoms and molecules and pursuing advanced engineering and biomedical applications. Techniques include the use of lasers and modern optics, microcomputers and other data acquisition systems.

The Laboratory is directed by Professor Michael S. Feld of the Department of Physics. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, are Assistant Directors.

An interdepartmental laboratory, the Spectroscopy Laboratory encourages participation and collaboration among researchers in various disciplines of science and engineering. Research contributors this past year were from several MIT departments, including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Chemical Engineering, Mechanical Engineering and Applied Biological Sciences. There were also numerous collaborations with outside academic institutions, many of an interdisciplinary nature, as well as with government, industrial and medical organizations.

This past year was one of continued growth. A new tunable laser research facility with UV resonance Raman capability became operational, and a laser biophysics laboratory is nearing completion. These facilities enhance our research capabilities in both the physical and biomedical sciences. In addition, a major new collaborative research program with the Cleveland Clinic Foundation was initiated in the field of laser spectroscopic imaging.

MIT LASER RESEARCH CENTER

The MIT Laser Research Center (LRC), a National Science Foundation Regional Instrumentation Facility housed in the Spectroscopy Laboratory, is now in its seventh year of operation. The LRC enables researchers from academic, industrial and other types of institutions to pursue research in broad areas of laser spectroscopy and dynamics, to develop new types of coherent sources and techniques, and to perform diagnostic studies of various substances and materials. Its unique facilities, which include a broad range of lasers and ancillary equipment, constitute one of the largest and best-equipped centers in the United States devoted to spectroscopic research. They are made available free of charge to qualified scientists and engineers from MIT and outside organizations.

MIT LASER BIOMEDICAL RESEARCH CENTER

The MIT Laser Biomedical Research Center (LBRC) is now in its second year of operation as a Biotechnology Resource Center of the National Institutes of Health. Biomedical applications of lasers and laser spectroscopy promise to change the face of medicine as it is currently practiced. The LBRC's charter is to develop the scientific understanding required for advanced clinical applications of lasers. LBRC activities can be grouped into four categories: Laser ablation and propagation of light in tissue; spectroscopic properties of cells and tissue; laser spectroscopic imaging; and laser welding and mediation of the healing process. In addition to core research, collaborative and outside research projects are conducted at the Center. Resources of the Center are provided free of charge, on a time-shared basis, to medical researchers who wish to pursue research in this important new field.

New laboratories and new equipment are being added to facilitate the programs of the two Centers. Currently, there are over 40 major laser systems. Equipment and facilities include continuous wave (CW) and pulsed dye lasers pumped by ion lasers, excimer lasers and Nd:YAG lasers; a tunable laser facility which provides intense pulses of light continuously tunable over the wavelength range 216-4500 nm; a picosecond laser laboratory; an infrared diode laser spectrometer tunable in the in 3-30μm wavelength region; UV and visible resonance Raman facilities; and equipment for performing spectrally resolved fluorescence microscopy and fluorescence lifetime studies. All laser systems are interfaced with microcomputers which control experiments and collect and analyze data. Auxiliary equipment includes a transient digitizer, fluorescence microscope and several optical multichannel spectral detectors.
Professor Stephen J. Lippard, of the Department of Chemistry, is studying the Raman spectral features associated with oxo-bridged polyiron moieties in biology. Continuing work on tetranuclear model compounds has led to the identification of a feature characteristic of the \([\text{Fe}_{4}O_{2}]^{6+}\) core in these compounds. The vibrational mode giving rise to this resonance-enhanced band has yet to be assigned. In addition, Dr. James Bentsen, also of the Chemistry Department, has begun studies on the protein methane monoxygenase in order to characterize the diron center proposed for this enzyme.

Professor Robert W. Field of the Department of Chemistry has made significant progress in characterizing the electronic structure of the gas phase CaO molecule. CaO is a prototype for all of the transition metal monoxides (MO), and illustrates how all electronic properties of MO may be derived from those of MF and NaO and those of MF from the atomic spectrum of M. This approach, which is radically different from traditional molecular orbital treatments, is particularly valuable because it reduces spectroscopically derived quantities to atomic properties which display periodicity and molecule-to-molecule transferability.

Professors Field and James L. Kinsey, also of the Department of Chemistry, continue their collaboration with Professor Richard Redington of the Texas Technical University Chemistry Department in a study of H-atom tunneling in tropolone. High resolution, supersonic jet, fluorescence excitation spectra have been recorded for several isotopomers, allowing definitive vibrational assignment of all observed features. The effects of vibrational excitations localized on heavy atoms remote from the O-H...O0 tunneling center are enormous and mode-specific, and they are being used to construct a potential energy surface for this intramolecular H-atom transfer process. This research provides valuable insight into the large effects of remote atoms on the dynamics of internally hydrogen-bonded biomolecules.

These systems are being investigated in connection with duplicating reaction mechanisms. Third, Dr. Charles Hamilton of the Department of Chemistry has obtained high quality supersonic jet spectra of the A-X systems of HCCH, HCCD, and DCCD. These spectra nearly complete the vibrational characterization of the A-state. Finally, Zeeman anticrossing spectroscopy has been used to measure the acetylene dissociation energy, a quantity of central importance and considerable controversy in models of hydrocarbon combustion.

Professor Henry I. Smith of the Department of Electrical Engineering and Computer Science is investigating the use of short wavelength (193nm) excimer laser light to make very fine period, sub-100nm gratings for use as diffraction elements in the soft x-ray range. A novel achromatic-holographic configuration has been developed and used to expose 100nm period (50 nm linewidth) gratings in PMMA. Further work is required to improve the cross-sectional profile of the exposed resist, and to convert the patterns into metallic grating structures. Such gratings are expected to improve the performance of a wide range of x-ray diagnostic instruments.

Professor Ioannis V. Yannas of the Department of Mechanical Engineering continues his studies of the microstructure of the dermis using small-angle light scattering, and has successfully used light scattering to quantify the orientation of collagen fibers in dermal tissues of guinea pig. Present experiments to quantify orientation of fibers in various species are in progress. The method has aided the analysis of neodermal structures synthesized by grafting full-thickness skin wounds with biologically active polymers based on collagen ("artificial skin").

Professor Steven R. Tannenbaum and Drs. Paul L. Skipper and Liang-Shang Gan, all of the Department of Applied Biological Sciences, are collaborating with Drs. Dasari and Michael Ottesen of the Spectroscopy Laboratory in the study of laser-induced fluorescence detection of fluorescent carcinogen bound protein and DNA adducts. The goal is to develop a sensitive and selective method for quantifying different carcinogen adduct levels in biological macromolecules such as proteins and DNA. Pulsed Nd:YAG laser-pumped DCM dye laser radiation (325nm) was employed to investigate the aflatoxin B1 serum albumin adduct level. A detection level of 10 picomole aflatoxin B1 per milligram of serum albumin (1.5 aflatoxin residue/100 protein) was easily achieved with a conventional PMT-equipped monochromator as a fluorescence detector. Current studies are focused on further increasing both the detection sensitivity and the detection selectivity.

Professor Mark S. Wrighton of the Department of Chemistry has been carrying out studies of the properties of multicomponent redox molecules. These systems are being investigated in connection with duplicating...
the essential functions of the photosynthetic apparatus; light absorption, charge separation, and catalytic redox chemistry. Dr. Robert J. McMahon, also of the Chemistry Department, and Visiting Scientist Howard H. Patterson, Professor of Chemistry at the University of Maine, have been working on the properties of a new molecule consisting of a viologen moiety covalently linked to a porphyrin derivative. The porphyrin is the light absorber and the viologen a primary electron acceptor, and Raman spectroscopy is being used to establish the nature of the events following photoexcitation of the porphyrin center. In another set of experiments with multicomponent redox molecules, Professor Wrighton and his collaborators are working to establish factors influencing the nature of excited state electron transfer to surface-confined biologen oligomers and other multi-component molecules. Transient Raman spectroscopy has been used to establish that high surface area SiO₂ modified with biologen oligomers will accept electrons from photoexcited Ru(2,2’-bipyridine)₃ in solution.

Professor Daniel Kleppner of the Department of Physics continues his studies of highly excited atoms in a strong magnetic field using high resolution laser spectroscopy. The problem bears on the question of how the classical concept of chaos relates to the underlying orderly behavior of quantum mechanical systems. The classical motion of an electron in the electric field of a proton and an applied uniform magnetic field displays a transition to chaos as the magnetic field is increased. The question arises as to whether there is a corresponding change in the quantum behavior of such a system. Theoretical studies indicate that the statistical properties of the spectrum should change qualitatively, but such a change has not been observed experimentally. Initial experimental results in the chaotic regime suggest that the spectral statistics are indeed different from those expected for orderly motion.

Professor David Pritchard of the Department of Physics and his colleagues have made important advances in the development of neutral atom traps. They have demonstrated the continuous loading of sodium atoms into a superconducting magnetic trap in which atoms with electron spin up were confined to a local minimum in the magnetic field. More than 10⁷ atoms have been trapped for ~100 sec. In addition, an atom trap based on the scattering force of near-resonant laser light has been developed in collaboration with Dr. Steven Chyung of AT&T Bell Laboratories, Holmdel, New Jersey. A 0.3 mm ball of sodium with a density more than 10¹⁵/cm³ has been observed for ~100 sec. In both experiments laser light cools the atoms to a temperature of about 1 millikelvin. These experiments advance the state-of-the-art in both number of atoms trapped and the confinement time by two to four orders of magnitude, and should permit interesting experiments to be conducted on these isolated, ultracold atomic gases.

Professor Regis M. Pelloux of the Department of Materials Science and Engineering continues to employ pulsed Nd:YAG laser radiation to introduce small surface defects in nickel-base superalloy specimens to serve as initiation sites. These sites, which are small in size (~10μm), dictate the use of laser radiation. The objective of this research is to establish criteria for lifetime predictions of critical jet engine components.

Professor Alan Davison of the Chemistry Department continues to investigate technetium complexes using resonance Raman spectroscopy. A metal-to-ligand vibrational mode of technetium-labeled metallothionein, a metal storage protein, was observed and identified by comparison with a variety of model compounds. Resonant enhancement allowed detection at concentrations as low as ca. 10⁻⁷ molar. Raman spectroscopy was also utilized to characterize a series of technetium dimers with aminocarboxylate ligands. These dimers possess strong metal-to-metal bonds and bridging oxo ligands.

Professor Alexander Rich and Drs. Andrew H.J. Wang and Gary Quigley, all of the Department of Biology, are studying the anthracycline closely related antibiotics daunomycin and adriamycin for use in treating human carcinomas. They have also studied the quinoxaline antibiotics echinomycin and triostin A, which are also anti-tumor agents. In an attempt to understand how DNA interacts with these drugs, they have been co-crystallized with various fragments of DNA of different lengths. The crystal structure of several drug complexes has been solved. The complexes with the quinoxaline antibiotics revealed an unusual conformational change with the introduction of novel hydrogen bonding interaction between the DNA bases. A number of chemically similar compounds have also been either isolated or synthesized, and the effects of specific chemical substitutions in these drugs have been correlated with biological activity.

Professor Rich and his colleagues also compared the structures of several daunomycin derivatives complexed to other DNA sequences. By solving these structures, the specific chemical alterations and their effects on complex formation, as well as on the mechanism of the action of the drug, can be elucidated.

Professor Alan J. Grodzinsky and Drs. Aryeh Weiss and Jeremy Hussmann, all of the Department of Electrical Engineering and Computer Science, along with Dr. Martin Yarmush of the Department of Chemical Engineering, are studying electrical control of protein transport across hydrogel membranes. Using fluorescence-labeled proteins and techniques developed in the Laser Research Center, they have shown the feasibility of controlled, sequential separation of proteins based on size and charge. This process has potentially important applications in the biotechnology of large scale cell culture separations, and in actively controlled drug delivery systems. Work is now in progress to maximize the electrically controlled changes in membrane transport by superposing processes including electrodiffusion, electroosmosis and electrophoretic motion of proteins within the membrane.
Professor Feld and his colleagues have initiated experiments to study spontaneous emission of single, isolated atoms in an open optical resonator. The method devised, which makes use of the large frequency degeneracy which can occur in confocal and concentric multimode resonators, is well suited to visible transitions, and thus extends past work, which utilized microwave transitions in Rydberg atoms. Resonance transitions of both barium and ytterbium atoms have been employed. By tuning the resonator through the atomic center frequency, both significant enhancement and suppression of the emission rate is observed. Further, radiative energy level shifts, a new manifestation of the Lamb shift, have also been measured. This work is part of a long term program to study superradiance and other coherent radiative processes in an optical resonator.

Professor Feld and Drs. Dasari, Michael Otteson and John E. Thomas and of the Spectroscopy Laboratory continue their research in laser-induced nuclear orientation (LINO), which has been successfully applied in a tabletop experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short lived (Lm) $^{85m}$Rb atoms. Present experiments seek to obtain sub-Doppler narrow tunable gamma resonances. In addition, these sub-Doppler LINO resonances provide a potential new method of producing tunable narrow-band polarized gamma rays.

Professor Feld and Drs. Thomas and Dasari have investigated a variety of quantum transport phenomena in atomic and molecular vapors using laser photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no classical analog. Results include direct inversion of two pulse echo data to obtain two-level optical radiator velocity changing collision kernels with a few cm/s resolution; magnetic state scattering kernels for isolated multipole moments; and development of a new tunable energy compensation technique to resolve velocity changes accompanying collision-induced molecular radiator reorientation.

Professor Feld and Drs. Carter Kittrell and Firooz Partovi, both of the Spectroscopy Laboratory, are engaged in biomedical research to understand the mechanisms governing laser ablation of tissue, for laser microsurgery and various percutaneous applications. A theory of thermal laser ablation has been formulated, and the dosimetry and damage predictions have been confirmed in experiments in human cadaver arteries using blue-green light. In addition, laser-induced fluorescence has been used to distinguish plaque, blood, and normal artery wall, and then to construct spectral maps of the interior of the artery. Part of this work has been conducted jointly with Dr. John Kramer of the Department of Cardiology of the Cleveland Clinic Foundation and Dr. Sipke Strikwerda of the Department of Cardiology of Leiden University Hospital. In parallel with this work, Drs. Feld, Kramer and Kittrell and Dr. Barry Sacks of Leonard Morse Hospital, Natick MA., along with Drs. Floyd Loop and Bruce Lytle of the Thoracic and Cardiovascular Surgery Department of the Cleveland Clinic Foundation, are developing a clinical system for diagnosing and treating atherosclerosis using laser light delivered percutaneously through optical fibers.
Laboratory for Nuclear Science

The Laboratory for Nuclear Science (LNS) provides support for research by faculty and research staff members primarily in the fields of basic nuclear and elementary particle physics, including the activities of the Center for Theoretical Physics in these fields. In addition, it provides a computing facility for its program. The primary experimental programs are in three areas. The largest local effort is in intermediate energy nuclear physics, centered at the Bates Linear Accelerator Center in Middleton, Massachusetts. The Laboratory also has a users group at the Los Alamos Meson Physics Facility (LAMPF). In high energy physics, there are major projects in the US at Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; and the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California. A third field is relativistic heavy ion physics with activities at Brookhaven National Laboratory (BNL). Abroad there are experiments which have recently been completed at the Germany Electron Synchrotron Laboratory (DESY) in Hamburg, Germany, at the European Center for Nuclear Research (CERN) in Geneva, Switzerland, and at the Gran Sasso Laboratory in Italy.

Intermediate Energy Nuclear Physics
The principle activity in this field is centered at the Bates Linear Accelerator Center, which is operated under the joint auspices of LNS and the Department of Energy. The Laboratory serves the national community, providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aiming at fundamental understanding of the nuclear force. The intermediate energy research programs of MIT faculty and research staff, both at Bates and at off-campus facilities, are described below; Bates developments are described in a separate contribution.

About twenty-five MIT graduate students were associated with the intermediate energy research program during the past year. A recent graduate, Douglas Beck, was awarded the Demos Prize, given annually for doctoral research and outstanding contributions at the Bates Laboratory; he is now a Senior Research Fellow at the California Institute of Technology. Another recent graduate, Charles Hyde-Wright, has been named a Presidential young investigator.

A large fraction of the intermediate energy faculty and senior research staff carried out at Bates in 1986 a difficult set of experiments on the tritium nucleus. The aim of the program is an extensive and precise characterization of the electromagnetic structure of three-body nuclei. This system is rather special in permitting a particularly sharp confrontation with theoretical expectations while still possessing a structure rich enough so as to bear upon a number of important issues. The technical challenge arose principally from the need to contain a large inventory of radioactive tritium in a geometry appropriate for precision experiments. The analysis of the inelastic data has just been completed. The integrated strength of the Coulomb response function demonstrates the important role played by short-range repulsive correlations in the nucleus. The response to magnetic probes confirms the importance of additional degrees of freedom in the nucleus (i.e., mesons and nucleon excitations).

The interest in few-body systems continues, with a major experiment aiming to measure the monopole and quadrupole charge distributions of the deuteron for the first time. It is perhaps surprising that these fundamental quantities are not yet known but, with the completion of several recent upgrades and with the construction of new experimental equipment, Bates will be the first laboratory in a position to make the measurement in an interesting regime. The experiment is just beginning and should be completed in the next fiscal year.

Precision electron scattering studies of the structure of more complex nuclei have continued. For example, an extensive study of $^{40}$Ca has ruled out a whole class of models which had been thought to explain the strength of "pion-like" states.

A major effort has been and will continue to be focused on studying nuclear response to large energy transfer. A benchmark coincidence study of protons knocked out of the nucleus by electrons is underway. The goals of the program include understanding single-nucleon motion in the nucleus, modifications of nuclear structure in the medium, and contributions to the electromagnetic current arising from the close interaction of two (or more) nucleons. In the last year, the first results in the region corresponding to nucleon excitation have done much to elucidate the underlying physics when the energy transfer to the nucleus is well beyond that needed to create pions.

Direct emission of single protons by intermediate energy photons has been studied over the last several years. An interesting scaling phenomenon has been found in comparing data for different energies and may provide the clue needed for extracting information about the probability for finding nucleons with very
large momentum in the nucleus. This in turn would be very instructive for understanding the short-distance structure of the nucleus. A difficult experiment examining the same process with neutron emission was carried out. This experiment is the first of its kind and should clarify the interpretation of these photo-nucleon reactions. The data analysis is in progress.

A unique test of the unified theory of electromagnetic and weak interactions, to be carried out at Bates, is in progress. The experiment aims to measure the very small asymmetry expected (~10^-7) in elastic scattering of right- and left-handed electrons from nuclei. A major obstacle for such an experiment is the need to produce a beam of polarized electrons; a high intensity (~50kAmp), highly polarized (~40%) beam was produced with a reasonable lifetime, allowing the experiment to go ahead. Upon completion of the parity experiment, we envision a robust program of polarized electron studies aimed at strong interaction physics (i.e., nuclear structure and reactions).

Complementary to the Bates experiments are investigations by the MIT groups at other accelerator facilities. The largest program is that examining selected pion-induced reactions at the Los Alamos Meson Physics Facility. This program aims at isolating pion interactions with nucleons and with nucleon clusters in the nuclear medium, particularly in the energy regime corresponding to the lowest excitation of the nucleon. In doing so, one expects to learn how internal nucleon structure affects the strong interaction of baryons. Both pion annihilation and charge-exchange reactions are being examined. The former have proved rather convincing in revealing many-body effects in the annihilation process, a process intimately connected with the origin of the nuclear force. Single and double charge exchange studies are isolating the pion interaction with nucleon pairs. Such a unified approach encompassing scattering from the absorption on nucleon clusters is essential for advancing our understanding of strong interaction dynamics. Recent coincidence results on single charge exchange point to shortcomings in our previous characterization of baryon-nucleon interactions.

The hypernuclei and solar neutrino group has joined the LVD collaboration at the Gran Sasso Laboratory in Italy in order to study cosmic neutrinos. Developments relevant to a future neutral current detector using inelastic neutrino scattering are being pursued.

Experimental High Energy Physics
The Electromagnetic Interactions (EMI) Group is engaged in two efforts in experimental high energy physics: one at the highest existing electron-positron colliding beam accelerator, PETRA, in Hamburg, Germany, and the other at the Electron-Positron accelerator, LEP, under construction in Geneva.

The work at LEP: The group is leading a large construction effort, which involves 380 Ph.D. physicists from 12 nations, to build a large, accurate detector to measure photons, electrons and muons precisely. The experiment is the first large-scale collaboration between physicists from the Soviet Union, the People's Republic of China, the United States, and Europe. The construction of this experiment is proceeding according to schedule and will be ready for data-taking by the time of the first LEP beam scheduled for early 1989. The purpose of this experiment is to understand the origin of the masses of elementary particles.

The work at PETRA: After its discovery of gluons, this group has concentrated on the study of the properties of gluons to increasingly high orders of accuracy. Of particular importance is the group's recent work on the determination of the second order constant between gluons and quarks, showing that the general theory of strong interactions between quarks and gluons is understood. In addition, they have shown that the expected sixth quark, known as the top quark, is much heavier than previously expected. Their measurement of direct muon production has yielded a much better understanding of the ways in which different quarks transform themselves into ordinary subatomic particles. The group is continuing to analyze the data with a new high resolution vertex chamber to study the lifetimes of new heavy particles.

UA1 Experiment
The UA1 group is studying proton-antiproton collisions at the CERN SppS Collider in Geneva, Switzerland. The physicists in UA1 are investigating many exciting phenomena in particle physics. After its discovery of the W and Z particles, the intermediate vector bosons predicted by the standard electroweak model, this group made a detailed analysis of the properties of these particles and of their production mechanism. One of the many results of this study was an upper limit on the number of light neutrino species in the universe (~6). The analysis of the production of heavy quarks (charm and beauty) led to the first observation of mixing between B^0 and B^{0*} mesons; such a mixing has only been observed so far in the K^0 -\bar{K}^0 system. A search for more fundamental particles such as a sixth quark (top), a new heavy lepton and various supersymmetric particles is taking place. This group is also presently building a position detector to be installed in the new Uranium-TMP (tetramethylpentane) calorimeter which is in preparation. In the mean time CERN is constructing a new antiproton accumulator which will allow an increase by a factor of 10 in the size of the data sample.
The Accelerator Physics Collaboration (APC) is conducting experimental research on the nature and interactions of photons, hadrons, and neutrinos. An experiment at FNAL completed three years ago, was designed to study how hadrons made up of one set of quarks generate hadrons with other types of quarks or other combinations of the same type of quarks. For this study, a unique device was developed that identifies each particle produced. The device, called CRISIS, worked well and should give information never previously available. The data from this experiment are currently being analyzed. Several papers have been published and six students have received their Ph.D.'s from this work. Studies are continuing on the question of hadron-nucleus collisions. This topic is of great interest, not only for high energy physics but also for heavy ion physics.

The group has taken data at FNAL in the world's highest energy neutrino beam. In this experiment one will be looking at a new domain in neutrino physics where new phenomena might be found.

This experiment used a holographic bubble chamber. The holographic bubble chamber is a new technique which takes a holographic picture of the bubble chambers. This technique was developed at MIT. The technique will provide a factor of ten improvement in resolution over conventional bubble chamber pictures. As noted above, the chamber has been built, is currently operating and meets all specifications. All of these experiments are being done in collaboration with a consortium of universities in Japan, China, Israel, Italy, France, and the United States.

The experiment in Gran Sasso Laboratory, which is the world's largest underground laboratory, will study particle physics problems and astrophysics problems. The particle physics problems are related to new radiation coming from Cygnus X-3. These studies might prove that Cygnus X-3 is a quark star which is emitting a new form of matter not yet seen on earth. In addition, this experiment can make the best measurement on the neutrino oscillation problem. From the point of view of astrophysics the detector will study the production of solar neutrinos by the sun, the yearly rate of collapsing stars in the universe and possibly point sources emitting high energy neutrinos. Since this experiment is an order of magnitude larger than previous type experiments, the probability is high that new phenomena might be found.

The Counter Spark Chamber (CSC) Group in a collaborative effort has constructed a major new detector for high energy neutrinos at FNAL. The initial experimental program for this apparatus is the detailed study of the weak neutral currents predicted on the basis of the electroweak theory and discovered experimentally several years ago. An experiment has been performed to study the nucleon structure functions associated with the neutral weak current. This detector, consisting of 350 tons of instrumented target material followed by a muon spectrometer, is now being used for a continuation of these studies with the newly commissioned Tevatron. The group is also collaborating in the construction of a high energy muon scattering facility at Fermilab which will be used with the Tevatron to study nucleon structure as well as the dynamics of quark jets in nuclear matter. This experiment is scheduled to begin taking data during 1987.

The major long term focus of the group is in the construction and exploitation of a new "state of the art" particle detector for use at the Stanford Linear Collider (SLC). This detector called the Stanford Large Detector (SLD) is now under construction and the CSC Group has a major responsibility for construction of the warm iron hadron calorimeter and muon detector. Installation of the detector will begin in 1987 and data taking will begin at the end of 1989.

The physics that will be pursued with this device is very exciting, and includes studies of the intermediate neutral boson ($Z^0$), search for the Higgs meson, and search for new leptons and super symmetric particles.

Lepton Quark Studies (LQS)
The LQS group is heavily engaged in the development and construction of the Central Drift Chamber for the SLD detector to be used in the SLAC (Stanford Linear Accelerator Center) Linear Collider (SLC). The Central Drift Chamber plays an essential role in the tracking of charged particles which is necessary for the identification of the standard $Z$, and possibly other new $Z$-like bosons, as well as for the identification of new heavy quarks. The final prototype chamber is presently under construction and will be used to test all design aspects of the actual Central Drift Chamber.

Relativistic Heavy-Ion Physics
Nuclei are normally kept apart by strong Coulomb repulsive forces. When nuclei collide with sufficient energy to overcome that barrier, a richness of phenomena is observed whose study has given us deep insights into nuclear properties. For almost two decades the "Heavy-Ion Group" at MIT has carried out these studies in order to investigate the properties of nuclei at the limits of their stability. How much angular momentum can a nucleus have before it flies apart? How many protons can it contain? How many neutrons? How far apart can the constituents be and still be part of the nucleus? Can nuclei form nuclear molecules? Accelerators have just become available which produce heavy nuclei with energies a thousandfold in excess of the Coulomb barrier so that we can now study nuclei at the limits of their density and energy. The interaction of extreme relativistic ions with targets as heavy as uranium is expected to produce matter densities and energy densities almost an order of magnitude greater than normal. New phases of nuclear
matter may appear. In these dense states a plasma may be formed from the quarks which make up the nuclei and the gluons which bind the quarks. The interactions at close quarters may break the bonds which confine the quarks and thus set them free. It is to these studies that the heavy-ion group is now committed.

The studies of these phenomena has begun with beams of 400 GeV silicon nuclei produced at Brookhaven National Laboratory. Neither the energy nor the mass of these initial beams is expected to be high enough to produce a quark-gluon plasma, but the conditions will still be an order of magnitude more extreme than any hitherto observed under controlled conditions. In the coming years we will accelerate heavier and heavier nuclei to higher and higher energies so as to reach further into the extremes of mass and density, extremes which will eventually approximate those that are conjectured to have occurred in the early stages of the expanding universe.

Particle Theory

The "standard theories" of the interaction of quarks and leptons through gauge fields are quantum chromodynamics (QCD) for the strong interactions, the Weinberg-Salam-Glashow theory for the electromagnetic and weak interactions and general relativity for gravitational interactions. They are powerful and in complete agreement with experiment, but they contain no answers to the fundamental question, why this particular hierarchy of particles and interactions? Clues can be sought within the structure of quantum field theory itself. In this direction the particle theory group has continued to explore the nature of anomalous gauge theories in which the quantization procedure destroys the classical symmetries. The theory of superstrings endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is totally inaccessible to experiment, this theory makes great use of internal consistency requirements. Members of the group have discovered an elegant geometrical formulation in which field equations appear from the requirement that the curvature of an infinite-dimensional complex space is zero. The group has also made new discoveries in the algebraic approach to the construction of string field theory.

Other members of the group have studied the physics which will become accessible with the next generation of experiments up to the superconducting super collider (SSC). It has been found that our present knowledge already severely restricts models in which quarks and leptons would themselves appear composite in these experiments. Among problems in the application of the standard theory studied by the group are the strange quark content of the proton and the effects of exchange of quarks between nucleons inside a nucleus.

The attempt to understand the beginning of the universe provides a drastic test of our theoretical assumptions. Members of the group have shown, using classical general relativity, that it is, in principle, impossible to create a whole new inflationary universe "in the laboratory", i.e., out of a concentration of energy in a small region. They will next study whether quantum fluctuations change this conclusion. Two spectacular astronomical events, the gamma ray burst of March 5, 1979, and the supernova of February 23, 1987, have stimulated research in the group. A scenario for the burst, making use of the group's ideas on strange matter, has been proposed. The information from the arrival times of the neutrinos from the supernova was used to place new limits on neutrino interactions.

Nuclear Theory

Nuclear theorists at MIT address a broad range of problems in contemporary nuclear physics. The research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role. Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

The role of quark substructure and QCD effects in nuclei is a growing focus of research, because of its fundamental significance and the unique resources in the Center for Theoretical Physics at the interface between nuclear and particle physics. One approach is to solve QCD numerically on a lattice, and efforts in lattice gauge theory range from technical developments to the study of magnetic monopoles and the properties of QCD at high temperature. A long-term objective is to calculate the nucleon on a lattice in order to test and distinguish between the various quark, bag and soliton models. The general theoretical problem of how to formulate effective operators in hadronic degrees of freedom relevant to conventional low energy nuclear physics is being studied in the context of a non-relativistic confining quark model. The bag model, which economically enforces the confinement aspects of QCD, is being used to explore the possibility of observing multiquark resonances in hadron scattering. A complementary description motivated by the large N limit of QCD, in which the only relevant degrees of freedom are meson fields, is being explored by studies of chiral and soliton models.

Relativistic heavy ion collisions comprise another area of growing activity motivated by the unique opportunity they provide for fundamental exploration of new regimes of matter, new and imminent experimental data, and the major new experimental effort in this field at MIT. A flux tube model has been developed in which two interpenetrating nuclei become color charged and generate a strong confined color field which creates quark-antiquark pairs. In this model, the hydrodynamic evolution of the plasma, the non-abelian
classical evolution of the color fields, deflagration of the flux tube, and fragmentation have been investigated. Another major focus has been the study of possible experimental signatures of the formation of a quark-gluon plasma. The results of this study, that strangeness production is a poor indication of plasma formation and that suppression of $J/\psi$ production by screening in the plasma is a promising possibility, are of great importance for the planning of new detectors and experiments.

Problems in the quantum theory of collective motion ranging from nuclear fission to the quantization of large amplitude vibrations involve periodic solutions to time dependent mean-field theory. Research has focussed on understanding the nature of periodic solutions to multidimensional classical systems and field theories and calculating periodic solutions for physical processes. Stochastic solution for many-body problems has proven valuable in a variety of applications, in addition, to lattice gauge theory, ranging from the exact solution of non-relativistic meson-nucleon field theory to calculation of the thermodynamic properties of quantum spin systems. An example of the strong interplay between many-body theory and field theory is the exploitation of the analogy between "deformed" gluon states in QCD and deformed nuclei.

Electromagnetic interactions are of great theoretical interest, because of the unique precision of electromagnetic probes. Important new questions involving coincidence experiments and polarization observables arise from the Bates Laboratory program and its upgrade. Much of the current work addresses coincidence experiments, ranging from fundamental studies of the reaction mechanism in proton knockout experiments, to explanations of how spin observables can be exploited to reveal new features of nuclear structure. Hadron scattering provides insight complementary to that obtained from electromagnetic probes. The role of intermediate isobars in medium energy reactions has been a central focus in intermediate energy research at MIT, and current investigations address the contribution of delta-nucleon collisions in $(\pi, \pi N)$ reactions and study the effects of intermediate isobar channels in nucleon-nucleon scattering.

Summary of Support
Participants in the various research programs during the past year amounted to approximately 430 people. This includes 53 academic staff members, 92 graduate students, and at least 30 undergraduates from MIT and other institutions. The latter were involved in senior theses, Undergraduate Research Opportunities Programs (UROP), work-study, and similar programs. There were 90 research staff members with Ph.D.'s including visitors and guests, and 165 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least fourteen Ph.D.'s, four M.S., and nine B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1987 from the contract with the US Department of Energy (DOE) is expected to total $21,956,000. This sum breaks down as follows: operations costs (salaries, wages, materials, services, travel, and overhead) were $15,115,000, of this $4,600,000 was for experimental and theoretical high energy physics, $8,900,000 was for intermediate nuclear energy physics for the support of the Bates Linac facility and research program both at Bates and elsewhere, and $1,615,000 was for nuclear structure theory, hypernuclei, and heavy ion experiments. Equipment costs are expected to total $6,141,000; of this, $4,996,000 will be for high energy physics and $1,145,000 for medium energy and heavy ion physics. A total of $800,000 will be expended for accelerator improvement and general plant and construction projects associated with the Bates Linear Accelerator Center. Support for other programs within LNS, including support from other institutions and laboratories for collaborative work undertaken directly by LNS, is expected to total about $1,900,000.
The George R. Wallace Jr., Astrophysical Observatory is a teaching and research observatory located in Westford, Massachusetts. Its facilities consist of a 24-inch reflecting telescope, a 16-inch reflecting telescope, several 8- and 14-inch telescopes, a 5 1/2-inch astrograph, and a small building that houses a workshop, darkroom, and observers' quarters.

This year the SNAPSHOT CCD camera was upgraded by Dr. Edward Dunham to allow guided exposures, and a new operating mode was implemented for recording spectrally resolved lunar occultations. This mode, with a slight modification, will also permit imaging long strips of the sky with the telescope fixed, by clocking the CCD in synchronism with the rotation of the Earth.

In conjunction with the "Telescience Project" the Observatory acquired two micorVAX GPX computers from Project Athena to facilitate control of imaging observations with the CCD camera from the campus. One computer will be located at the Observatory and be the communication gateway between the CCD camera and a high-speed communication line, while the campus computer will serve as the data receiver and control console for the observer. The Telescience Project is being carried out by Richard Baron(grad), Dr. Edward Dunham, and several UROP students.

Last fall 65 students in the courses 12S23 ("Observing the Stars and Planets") and 8.287J-12.117J ("Observational Techniques of Optical Astronomy"), taught by Dr. Linda French and Professor James Elliot, used the observatory for their laboratory work. In the spring, 42 students from 12S23 and the advanced projects course 12.118 ("Project in Optical Astronomy") also used the observatory facilities.

Student research at the observatory included the development of a searching technique for the new asteroids as a senior thesis by Amanda Bosh (Class of 1987); Olga Kuhn (Class of 1988) worked with her. Jennifer Wiseman (Class of 1987) did photometry of Comet Wiseman-Skiff, which she discovered at the Astronomy Field Camp at Lowell Observatory (Flagstaff, Arizona). The Field Camp is a regular IAP activity that is jointly sponsored by the Observatory and the Department of Earth, Atmospheric, and Planetary Sciences. Steve Slivan (grad.) carried out a program of observing mutual occultations and eclipses of Pluto and its satellite Charon.

Dr. Dunham, Dr. Nathanial White (Lowell Observatory), Mark Griffith (grad.), and David Osip (Class of 1989) observed several spectrally resolved lunar occultations this spring with the SNAPSHOT. From these data they hope to learn the structure of the outer stellar coronas.

JAMES L. ELLIOT
The story is told about a young sailor who leaned against the Queen Mary, on the dock at Southampton and, at that very moment, the massive vessel began to move from the dock. The sailor walked away with a broad smile across his face, not wanting to know more about the details of the forces that had caused the movement.

At the end of a long academic year, I understand very well how the young sailor felt. In a place as large and complex as MIT, there should be no illusions about the impact that the efforts of any individual or any group may have on institutional progress. But there was progress on several fronts during the year, and there certainly was effort -- significant team effort, expended by the women and the men who work in the areas for which I am responsible. So, in the spirit of the story of the sailor and the Queen Mary, I wish to enter here some footnotes to the chronicle of a busy and productive year. A full account of departmental activities will be found in the pages that follow this prefatory comment.

The bottom line, as I see it, is not new: our goal in the people services is to strive for pluralism and for improving the quality of the experience for all who work and who study at MIT. The year's record is one of some progress, and the prospect is one of yet a greater challenge that lies ahead of us.

From a record number of applicants (20 percent higher than ever experienced in MIT history), we selected a Freshman Class more diverse in backgrounds and interests, by any standard one might apply, and more accomplished -- more distinguished, if the term can apply to 18-year-olds -- than ever before. The same is basically true of an equal number of entering graduate students, admitted by over 20 departments and programs. In the period of the past 12 months, we awarded nearly 3,000 degrees to yet another group of talented young men and women.

Each year MIT enrolls and graduates a long line of students who bring here and take from here what the late Vannevar Bush called the habit of success. Their academic work is superior. They are here to learn and to achieve. And a lot more happens to them while they are here. Based on a survey of former black students, we published last fall a frank report about the racial climate on campus. The report painted a stark, realistic, and indeed worrisome picture of how we fail to take full advantage of the kaleidoscope of individual differences that are found among MIT people. We are quite successful in attracting a group that is diverse in geographic, economic, and cultural terms, but then we are clumsy, and in some cases inept, at capitalizing upon that diversity. Pluralism, as the report pointed out, is a goal that does not stop with diversity but includes understanding and appreciating differences and cherishing, learning, and building upon diversity. We have a long way to go to reach that goal, but we took significant steps forward during the year, to face up to our problems openly and to recognize the need for more work and improvement. The successful response to the report on racism depended critically on each department and each working unit taking the report's findings and translating them into the group's own issues and agenda. Our goal of pluralism carries, as well, into the scope and the nature of the services we provide for people, not just the composition of our community. Personnel and athletics, career services and development, health care services, our publishing, and our public relations activities, all strive to provide more and better choices, flexibility, and improved quality of experience for MIT people.

Last spring we launched a major university-wide review of benefits with these goals in mind. Its first outcome will be some changes in our package of benefits and an improved communications program to be put into effect next winter. The review will continue intensively over the next year and probably longer. We have engaged a full-time consultant, Edward W. Powers, to manage the review project under the guidance of the Director of Personnel. A steering committee of MIT senior officers will review recommendations for change. Members of the community have been invited to contribute their ideas and suggestions.

Midway through the year, Dr. Arnold N. Weinberg and Linda L. Rounds assumed their new positions as Medical Director and Executive Director of the Medical Department. Under the guidance of the Medical Management Board, the Department now finds itself immersed in intensive programs to reach out to the student community with educational and other services. It is focusing, also, on efforts to innovate and to enhance the quality, the management, and the variety of the medical service it provides to the community. It does so amidst a remarkably volatile and competitive local market for the delivery of health care.

Many months of planning and debate last winter led to the President's decision to approve a program of differential self-help in an effort to make MIT more easily -- and more visibly -- accessible to students from families who are least able to support them. Both Admissions and the staff in Career Services -- together with Financial Aid and other MIT offices -- geared up to implement and to market this program.
next year. We want to attract into our applicant pool minority and other students to whom the financial barriers of attending MIT appear to be prohibitive. Moreover, the Admissions Office launched during the year a sophisticated modern program of general publications. These publications have received very positive comment from alumni, from secondary schools, and from within the MIT community.

Our new Director of the News Office, Kenneth D. Campbell, in his first full year on this post, has worked diligently on staffing up for new initiatives to enhance the presentation of MIT to the public. The need for effective publicity is especially felt as we embark on MIT's most ambitious drive ever to raise new resources for the future. The MIT Campaign for the Future calls for a massive mobilization of human resources from every part of MIT. In this extraordinary effort to come up with a clear and forceful articulation of this university's goals, needs, and promises, I would like to single out the contributions of a close associate and long-time colleague, Kathryn W. Lombardi. Ms. Lombardi serves on our management team as director of MIT's public relations services, while also serving as the President's Executive Assistant. She brings to her work a creative blend of new ideas, wisdom, and in-depth knowledge of MIT. She has a knack for seeing the whole picture, and a clear and polished style for helping to conceptualize and to articulate the university's agenda. Last year she made cardinal contributions to the plans for the new Campaign. Her boundless personal energy and her ingenuity in the planning of building dedications and other major public events have been indispensable. She is joined in the masterminding of large campus events by one of her key managers, Mary L. Morrissey, the director of the special events and Information Center. I have already acknowledged Miss Morrissey's work in my report as Secretary of the Corporation. Over the past few years she has become MIT's Grand Marshal of all important events. Together the two women epitomize for me what imaginative leadership is all about in the service business. MIT is in their debt.

CONSTANTINE B. SIMONIDES
The 1986-87 year in Equal Opportunity and Affirmative Action can be described as one of cultivating a spirit of constructive dissatisfaction with current performance among the senior officers and managers of the Institute. This is especially true in the academic area. Three major steps have been put in place for more exact measurement of performance regarding the recruitment and retention of minorities and women in the workforce. First, we have reviewed affirmative action results and experiences by each senior officer's area based on a uniform six-month report of progress in all categories of employment.

Second, the Equal Opportunity Committee continued its activity with selective academic departments whereby a dedicated faculty member of a department would provide, through an intensive talent research, a list of possible black and Hispanic candidates for faculty positions. Supplementing this activity, there have been Equal Opportunity Committee meetings with specific academic department heads. The purpose was to review what has been successful in recruitment of female and underrepresented minority faculty and establish some understanding of the department's projection for the next two years regarding underrepresented minority and women faculty appointments.

Third, with the past year's successful recruitment of minority administrative staff, the Equal Opportunity Staff Group initiated activities to enhance retention of these newcomers to the Institute. Among these steps taken was the Octoberfest, a reception designed to introduce new minority employees to the senior administration and to other staff across departmental lines.

The above steps have allowed the Institute to analyze the current situation (where we are today versus where we want to be); to step up the expectations of the senior management and to point to ways to improve our efforts; and to develop an action plan (a few models or success stories in place). We are now in a position to encourage all segments of the institution to determine who are the successful performers and high-potential administrators in the quest to increase the presence of minorities and women at the Institute. The data below tells where greater efforts are needed.

The current workforce is 13 percent minority (five percent Black American, seven percent Asian American, and one percent Hispanic American) and 87 percent non-minority; 37 percent female and 63 percent male. These numbers represent no change in the total women and minority employment statistics from last year.

During the past year there have been no significant number changes for women and minorities on the faculty and administrative staff. There are some positive actions, however, worth noting here. Lincoln Laboratory appointed the first underrepresented minority scientist to its Steering Committee by promoting Dr. Wade Kornegay to Associate Division Head. Professor Sallie W. Chisholm of the Department of Civil Engineering, has been appointed to serve as Associate Chair of the Faculty. Senior Lecturer Ruth Perry, Director of the Women Studies Program received a Guggenheim Fellowship, and was awarded tenure. For the contributions made by Professor Phyllis A. Wallace, the Alfred P. Sloan School of Management established this past year a Phyllis A. Wallace Doctoral Fellows Fund, the income from which, will provide support for black students admitted to the Sloan School Doctoral Program, and a Visiting Scholars Fund under her name to provide support for black visiting scholars at the School. Dr. Clarence C. Williams the Assistant Equal Opportunity Officer on received the Affirmative Action Award at the Annual Awards Affairs of Freedom House in Roxbury; on November 19, 1986.

Other highlights for this year should be mentioned. First, the Institute continues to provide role models for minority youngsters through its participation in the Black Achievers Program of the Greater Boston YMCA. MIT was represented in the local community: the Assistant Equal Opportunity Officer served as President of Massachusetts Pre-Engineering Program, a program designed to assist minority pre-college students academically to enroll and graduate from a four year undergraduate engineering and science-based program. He also served as President of the Greater Boston Inter-University Council, a local organization of minority administrators initiated to develop activities that enhance retention of minority students at local colleges and universities.

The Institute's Dedication of a major academic building in the name of the deceased Astronaut Ronald E. McNair, a Ph.D. graduate of MIT underscored the value and stature of this hero not only for future generations of young people at MIT but for others throughout this Country.

Clarence G. Williams
Assistant Equal Opportunity Officer
This year brought an encouraging response to our efforts to enlarge and broaden the pool of applicants to MIT. Efforts initiated last year were supplemented by a new audio-visual presentation which was very well received. The addition of a second person to concentrate on minority recruitment and the promotion of Eduardo Grado to be Coordinator of Minority Recruiting allowed increased focus and activity in that area.

The result was an increase in applications of 18 percent including an increase of 19 percent from women and 42 percent from underrepresented minorities. We expect the incoming freshman class to be 36 percent women, a slight decline from last year but well above previous years. Underrepresented minority students will account for over 13 percent of the class compared to just over 10 percent in 1986 and under 9 percent in 1985.

Our efforts to broaden the student body were further reflected in the apparent solving of the overenrollment problem in Course VI. The class entering in 1986 will, based on Spring of 1987 projections, be the first to not exceed the desired limit on concentrators in Course VI. The class entering in 1987 will include even fewer students indicating an interest in that area.

Finally the incoming class is stronger than last year's on every relevant measure of academic strength.

During the year we pursued several initiatives designed to further enlarge and broaden the applicant pool. Work was substantially completed on a new set of publications. An introductory brochure was mailed to outstanding juniors in high school. A more detailed "Freshman Prospectus" and a special brochure for minority students are being completed. During the spring we opened a new reception and information center for visitors. We also initiated the production on campus of what we hope will be the first in a series of special topic videos which will be available for viewing in the visitors center. The first video is on residential life. A two-year effort to produce a self-guided tour for visitors was completed in cooperation with Campus Information Services.

A highlight of the year was gaining approval for a program of differential self-help for our lowest income students. We hope we can use this program to encourage more such students, and especially underrepresented minorities, to consider MIT.

Perhaps the biggest change was the implementation of our new system for evaluating applications. The new system attracted many more readers from the faculty and administrative staff and reaction was overwhelmingly positive.

Finally, we made progress on a number of fronts in our recording and use of data and our carrying out of research projects. Among the more important were the development of an inquiry database and of a standard Admissions Summary Report. The inquiry database will allow us to monitor the distribution of our literature. This is especially important in view of the increased cost of our new publications. It also allows us to track applicants from their first contact with MIT. The standard summary reports will allow us to build a database for longitudinal studies. Data was made more accessible to the staff through the purchase of a number of personal computers.

These new initiatives promise continued success in increasing the breadth and excellence of the student body at MIT.
# ADMISSIONS TRENDS 1978 - 87

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary applications</td>
<td>9,320</td>
<td>10,274</td>
<td>11,223</td>
<td>12,526</td>
<td>12,525</td>
<td>12,653</td>
<td>12,465</td>
<td>14,698</td>
<td>14,349</td>
<td>16,237</td>
</tr>
<tr>
<td>Final applications</td>
<td>4,870</td>
<td>5,368</td>
<td>5,677</td>
<td>5,922</td>
<td>5,921</td>
<td>5,959</td>
<td>6,055</td>
<td>5,747</td>
<td>6,213</td>
<td>7,372</td>
</tr>
<tr>
<td>Admissions offered</td>
<td>1,865</td>
<td>1,813</td>
<td>1,809</td>
<td>1,909</td>
<td>1,911</td>
<td>1,818</td>
<td>1,854</td>
<td>1,885</td>
<td>1,762</td>
<td>1,826</td>
</tr>
<tr>
<td>Actual registration</td>
<td>1,059</td>
<td>1,057</td>
<td>1,081</td>
<td>1,030</td>
<td>1,109</td>
<td>1,082</td>
<td>1,059</td>
<td>1,061</td>
<td>1,001</td>
<td>1,012</td>
</tr>
<tr>
<td>Registrations as percent of admissions</td>
<td>56.7%</td>
<td>58.4%</td>
<td>59.7%</td>
<td>54.0%</td>
<td>57.5%</td>
<td>61.1%</td>
<td>57.1%</td>
<td>56.2%</td>
<td>57.0%</td>
<td>55.4%</td>
</tr>
<tr>
<td>Number of secondary schools represented</td>
<td>877</td>
<td>893</td>
<td>894</td>
<td>835</td>
<td>842</td>
<td>891</td>
<td>722</td>
<td>860</td>
<td>830</td>
<td>848</td>
</tr>
<tr>
<td>Percent of students from 9 northeastern states</td>
<td>50.6%</td>
<td>49.0%</td>
<td>47.8%</td>
<td>51.9%</td>
<td>51.0%</td>
<td>50.5%</td>
<td>50.5%</td>
<td>44.7%</td>
<td>43.5%</td>
<td>39.8%</td>
</tr>
</tbody>
</table>

| College Transfers               |        |        |        |        |        |        |        |        |        |        |
| Total applications              | 1,074  | 1,143  | 1,131  | 818   | 1,378  | 1,024  | 1,048  | 909   | 890   | 870   |
| Applications completed          | 535    | 486    | 471    | 399   | 425    | 400    | 304    | 295   | 317   | 304   |
| Admissions offered              | 172    | 152    | 167    | 93    | 118    | 128    | 124    | 131   | 137   | 106   |
| Actual registrations            | 123    | 124    | 119    | 76    | 82     | 91     | 91     | 101   | 97    | 79*   |
| Registrations as percent of admissions | 72% | 82% | 71% | 82% | 69% | 71% | 73% | 77% | 71% | 69% |

| Graduate Students               |        |        |        |        |        |        |        |        |        |        |
| Total applications              | 7,454  | 7,849  | 7,832  | 9,075  | 9,342  | 8,836  | 7,922  | 8,032  | 8,564  | 8,443  |
| Admissions offered              | 2,724  | 2,636  | 2,380  | 2,926  | 2,920  | 3,007  | 2,223  | 2,467  | 2,457  | 2,204  |
| Actual registrations            | 1,461  | 1,362  | 1,212  | 1,465  | 1,476  | 1,542  | 1,290  | 1,338  | 1,105  | 1,067**|
| Registrations as percent of admissions | 54% | 52% | 51% | 50% | 51% | 51% | 58% | 54% | 49% | 48% |

*responses still coming in  
**expected to register
Alumni/ae totalling 1,575 served as Educational Counselors this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, The Virgin Islands, and 44 foreign countries. This group included 250 women and 62 minorities (45 Blacks, 7 Puerto Ricans, and 10 Mexican-Americans). The Educational Counselors represented MIT at over 200 local College Fair programs; they conducted over 7,400 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 95.6 percent (98.3 percent within the United States) were interviewed by a local Educational Counselor.

Project Contact is a program which puts current undergraduates in touch with applicants, Educational Counselors, and school personnel. This past year 350 students, representing 130 different geographic areas (including 17 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 33 cities throughout the United States by Educational Council groups. Twenty-one of these meetings were held during MIT’s Spring Break and I organized panels of current students to speak of each of these meetings.

MIT Open House Meetings were held throughout the United States in the fall. Local Educational Council members assisted members of the Admissions staff in arranging for 118 Central Meetings in 103 cities.

Another program supported by the EC office was the AMITA High School Visiting Program. Marti Ward ran this program, and coordinated the efforts of 80 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women’s professional organizations) to visit 40 high schools throughout the Greater Boston Metropolitan Area. They spread the word to young women (and in some cases young men) about the importance of continuing to study math and science in order to keep career options open.

A pilot AMITA High School Visiting Program was run in Los Angeles with the assistance of Educational Council member Sue Kayton ’78. Approximately 20 women made visits to nine high schools. Plans are underway to expand this program with the assistance of Cal Tech.

BONNY S. KELLERMANN
I. Summary

The academic year 1986-87 has been one of transition for our Department and I would like to make particular mention of the extraordinary patience and understanding of our instructors, coaches and staff. Further, I would underscore the important fact that despite the difficulties of shifting management functions, numerous clerical changes, occasional unfilled positions, and frequent unplayable field conditions the Department should take considerable satisfaction in the knowledge that 1986-87 was one of our most successful in levels of student participation as well as in both individual and team achievements.

Record participation levels of my seven year tenure as Director were reached in men's and women's intercollegiate athletics, club programs and physical education registration. This is despite seven year lows for the same period in numbers of male and total undergraduates. Graduate student program involvement continues to rise apparently keeping pace with increases in graduate enrollment. Intramurals show a slight dropoff in overall numbers of teams and cumulative student participation, but continue to function at healthy levels.

As I mentioned at the Awards Convocation, we had the largest number of appropriate student award nominees since Convocation records were kept. Four MIT students were selected for academic all-American with one, Martha Beverage, selected in both basketball and field hockey. Several intercollegiate teams enjoyed their best record in MIT history. Two coaches, Professors John Benedick and Gordon Kelly, were named New England Coach of the Year in their respective sports of women's swimming and indoor track and field.

Included with this report are three exhibits providing our annual participation statistics with comparisons to the two previous years (Exhibit I) and last fall's most recent Five Year Long Term Objectives (Exhibit II) and Current Year Priorities (Exhibit III).

Under separate cover for the Institute Archives we will submit the annual statistical review of our wide-ranging program participation levels and achievements as well as a recap of our various athletic card sales and our 1986-87 staff changes.

II. Highlights of the 1986-87 Academic Year

Department-wide:
- Completion of a year-long series of top management organization shifts in response to our Department's on-going commitment to professional development, job enrichment and leadership preparation.
- Planning and installation of an acknowledged "state-of-the-art" synthetic all weather outdoor playing field (Jack Barry Field) on the space known formerly as Area A. The field provides four marked intercollegiate playing areas (football, soccer, lacrosse, and field hockey) plus the option of two corner softball fields or three contiguous sideways fields at right angles to the intercollegiate fields for simultaneous intramural competitions in touch football, soccer or ultimate frisbee.
- Identification and hire of three full-time minority employees: Leo Osgood, Assistant Professor and Head Coach of Basketball, Jose Rivera, Assistant Athletic Trainer in Sports Medicine, and Barrington Cornwall, Athletic Utility.
- Initiation, in concert with the MIT Health Plan, of an experimental series of health fitness program opportunities for members of the MIT Health Plan. This joint pilot program (called MIT FIT Plan) includes 7:00 a.m.-11:00 a.m. Swimming, 7:15 a.m. Aerobic exercise classes and admission to all open ice skating sessions. The experiment will be expanded next year to include use of the MIT Sailing Pavilion and the MIT indoor running track.
- Launching of a participation test summer Saturday opening of du Pont Athletic Center to assess the increase of on-campus graduate students and the resultant increase/need for weekend exercise/athletic facilities. Early indications suggest an established and growing need for some summer Saturday "acility availability.
Physical Education:
- The new high of 7004 student registrations is actually +573 registrations higher than the average of the past five years. There was also a new high of 2557 non-credit student registrations which is a particularly impressive confirmation of physical education program quality and interest.

- Continuing steady improvement in the three phase instructor evaluation system (student, staff committee, director of Physical Education) with increased amounts of data and growing trust in the process by our instructors.

- Successful completion of the first full year of computerization with most of the "bugs" removed and with the computer component viewed by the entire staff, including clerical, as a definite asset.

- Growth of Physical Education Summer Programs bringing total offerings to nine with the addition of tennis and sculling. All of our summer programs are now under the same consistent management and fee structure. Most of the programs allow undergraduates to acquire credit toward fulfilling physical education requirements. This option is expected to become an increasingly welcomed summer alternative for on-campus undergraduates.

Intramurals:
- Implementation of the newly developed IM Student Management and Referee System basically designed to upgrade the selection and training for these crucial positions.

- Publication of a revised and clarified IM Sports Handbook to encourage greater participation and smooth the student management process.

Intercollegiates:
- Men's and Women's intercollegiate varsity teams enjoyed one of their most successful years of competition in 1986-87 posting an overall record of 295 wins, 218 losses and 4 ties for a combined .574 winning percentage (vs .563 a year ago). Three programs - Golf, Ice Hockey and combined Indoor-Outdoor Track - all enjoyed the most victories in their program history at MIT.

- Of the 11 women's teams recording won-loss records, six had winning records with an overall .554 winning percentage (vs .557 a year ago). Women's basketball enjoyed their best record ever with 14 wins, 10 losses and selection for post-season play. Soccer was selected for the Massachusetts Women's Intercollegiate Athletic Association Championship in only their second year of varsity status. Tennis won the same Massachusetts Women's Association Class B Championship. Volleyball was ranked 9th nationally in Division III (Women's).

- The New England Women's 6 playing conference, founded two years ago under the driving force leadership of MIT's Professor Jane Betts, the first league president, has voted in two new conference members - WPI and Mount Holyoke - and voted a change in conference name to New England Women's 8. (The six charter members: Babson College, Brandeis University, MIT, Smith College, Wellesley College, and Wheaton College). The expanded conference began year one with championships in tennis, cross country and basketball. Year two saw the addition of soccer and by 1988-89 the conference will have added volleyball, field hockey, lacrosse, and softball for an impressive total of eight conference competitions. The concept and development of this conference has been extremely well received by the students and coaches of the six charter institutions and has proved to be a crucial factor in the enrichment of Division III women's intercollegiate competition in Massachusetts.

- In November, 1986 MIT hosted the second Co-educational Basketball Classic (David Koch '62 Co-Ed Basketball Classic). The event inspired the Department, brought together outstanding competitive activity for both men and women, and successfully honored former MIT basketball star and current major financial support David Koch, Class of 1962. The other institutions were University of Chicago, University of Rochester and Washington University of St. Louis.

Special Events:
- MIT hosted an increased variety of special events of local, statewide and national public interest and public relations value in addition to the David Koch Classic. Some of the most effective include:

  - **Crash B Sprints World Indoor Rowing Championships** with coverage in Sports Illustrated Magazine.
  - **Massachusetts State Police Junior Olympics** with competition among 10-14 year old boys and girls from around the State of Massachusetts.
  - **Bay State Games** - involving six MIT athletic facilities and nine different athletic programs.
  - **United States Fencing Association National Collegiate Championship**
Sports Medicine:
- In addition to the 18 month identification and hire process for minority assistant trainer Jose Rivera, Coordinator Paul Grace has particularly highlighted:

  - **Physical Fitness Assessment Program** - increased participation and solidification of testing and educational procedures, has expanded understanding of the values of lifetime fitness throughout the MIT Community.

  - **Initiation of an injury/accident prevention program** designed for education of MIT Intercollegiate coaches. We will analyze the results through the 1987-88 year.

  - **Class of 1974 Health Fitness Center** continues to experience increases in participation and gradually improving facilities to keep pace with the interest. An improved ventilation system has made a significant improvement in the fall and winter environment. Summer and early fall heat and humidity continue to be a problem with air conditioning perhaps the only answer.

  - We are pleased to report that our Coordinator of Sports Medicine, Paul Grace, has assumed the additional responsibility for supervision of all our equipment purchases and distribution. Paul's dedication and managerial abilities will be well utilized in the natural and important linkage of Sports Medicine and equipment safety. Paul is replacing John Murphy who is preparing to retire from full-time responsibilities in August, 1987 after 39 years of continuous service to MIT. "Murph" will continue as a part-time member of the equipment group in the newly named "John H. Murphy Equipment Center" as voted by the Executive Committee of the MIT Corporation on May 30, 1987. More will be said in next year's report, but I want to underscore President Gray's personal observation to Murph that the naming of the Equipment Center was directly linked to the hundreds and hundreds of MIT athletes who have treasured Murph's friendship and support. Paul Gray counts himself among that group as do I and his many friends in the Department and throughout the Institute.

III. Future Considerations

We continue to focus future planning on our Department's ability to anticipate and respond to the MIT Community's changing and growing needs in the 1990's and beyond. In this regard we have several important initiatives to be developed further in 1987-88:

**Athletic Department Tenure Policy:**
The faculty of the MIT Athletic Board are working closely with Department Administration and the Office of the President to seek an appropriate and responsible "non-tenure system" for Athletic faculty.

The appropriate system must sustain the MIT concept of our instructors/coaches as integral to the educational process while resolving the current inconsistencies and inequities both in relation to the MIT academic faculty tenure process and within our own Department.

Our Department's most recent tenure decision process this past year took a step in the right direction by adding an Athletic Board faculty review of the Department recommendation prior to Academic Council decision. This additional step was well received and will be included in future such decisions pending other decisions on Department tenure policy in 1987-88.

**Physical Education Program Quality:**
The new high in physical education registrations is serving as further impetus for Director Gordon Kelly and Assistant Director Candy Royer to focus 1987-88 agenda on significant improvements in program quality. It is our intent to concentrate on the theme of "Physical Education Program Excellence" in our April 1988 Visiting Committee meetings.

In the coming months the Physical Education unit will develop a staff consensus on a statement of Mission, Goals and Objectives. This statement will serve as a cornerstone for detailed reviews of every facet of the MIT Physical Education Program in providing our students with well rounded, relevant and effective course offerings and teaching, and also in providing our instructors with dynamic and supportive training opportunities, motivation and evaluation.

**Physical Plant/Athletic Department Workforce Balance:**
At issue here is the most effective way to provide the necessary maintenance and preparation services for our wide range of outdoor fields and other synthetic surfaces. This concern is certainly one reason for our decision to convert Area A to a synthetic all weather surface and for our plans to
convert the Har-Tru du Pont Tennis Courts to a maintenance free all weather synthetic surface.

This situation leads us to believe we might be able to improve support service and efficiency if the Athletic Department were to independently employ and supervise outdoor facility personnel in a manner similar to our current arrangements with our indoor athletic utility group.

We intend to continue discussions with Physical Plant on the subject despite the fact that initial conversations among the middle managers of both Departments have raised serious questions about the practicality of such a move.

Athletic Facilities:
We continue to plan, promote and monitor the improvement and/or construction of athletic buildings and outdoor fields and other surfaces. We will begin shortly the conversion of the six du Pont Har-Tru Tennis Courts to a synthetic all weather surface. Concurrently, we will resurface the five synthetic tennis courts on the most western side of the du Pont complex.

Additional high priority facility plans in the coming year include further efforts to launch renovation of Alumni Pool (our highest priority); renovation of Pierce Boathouse locker rooms to provide equity for the changing volume ratios of men and women student rowers; lighting improvement in the MIT Athletics Center indoor track/tennis area to upgrade playing conditions for tennis and other activities that take place in the track infield; significant reduction in the stiffness/hardness of the multi-purpose synthetic surfaces in Rockwell Cage and the track/infield in the MIT Athletics Center. We have conducted stiffness tests on both surfaces using the services of Professor George Platt of Electrical Engineering. The conclusion is that both surfaces are extremely unyielding (+110,000 pounds per foot vs. ideal stiffness level of 29,000 pounds) and much too hard for healthy regular student athletic participation.

Beginning with this report we will include a full listing of athletic facility priority needs as an archive exhibit for periodic update.

In closing, I will say again this has been a good year with outstanding effort by a great many dedicated people. I want to make particular mention of valued colleagues who will be leaving our Department. Bob Bayliss, Assistant Professor and Head Coach of Men's Squash and Tennis will become Head Coach of Tennis at the University of Notre Dame. During Professor Bayliss's three year tenure MIT Men's Tennis enjoyed a significant improvement in individual and team success including an unprecedented two consecutive New England Championships. He will be missed. We wish him success in his new responsibilities. Ann Yelmokas, part-time Assistant Coach of Swimming, leaves to take a full-time position at Boston University after four years of outstanding contribution to Head Coach John Benedick and the MIT Men's and Women's Swim Teams. Her spirit, commitment and leadership meant a great deal to all of us. Jack Barry, Associate Professor and Assistant Director of Athletics, retires as a full-time member of our Department to continue as a part-time Head Coach of Golf. Jack has contributed special service of exceptional merit to MIT for almost 30 years through his leadership and achievements as a teacher, coach, counselor, administrator, and friend. We are pleased that his golf students will continue to receive the benefits of his talents. We are all honored by the recent action of the MIT Executive Committee of the Corporation in voting to name Area A - our new Omni Field - in Jack's honor. The Office of the President's official letter said in part, "The Jack Barry Field will be a proud and permanent reminder to all of us, and to the MIT generations of the future, of an untiring, dedicated, and resourceful leader, teacher and coach who has had a hand in making this a better place to live, to study, and, yes, to play."

ROYCE N. FLIPPIN, JR.
EXHIBIT I
MIT ATHLETIC PROGRAM PARTICIPATION

<table>
<thead>
<tr>
<th>STUDENT ENROLLMENT</th>
<th>Report Year</th>
<th>1986-87</th>
<th>1985-86</th>
<th>1984-85</th>
</tr>
</thead>
<tbody>
<tr>
<td>(October Figures -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Includes Specials)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergrad Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,295</td>
<td>1,165</td>
<td>1,137</td>
</tr>
<tr>
<td>Undergrad Men</td>
<td></td>
<td>3,148</td>
<td>3,376</td>
<td>3,379</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>4,443</td>
<td>4,541</td>
<td>4,536</td>
</tr>
<tr>
<td>Graduate Women</td>
<td></td>
<td>1,045</td>
<td>1,042</td>
<td>1,054</td>
</tr>
<tr>
<td>Graduate Men</td>
<td></td>
<td>4,268</td>
<td>4,204</td>
<td>4,036</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>5,313</td>
<td>5,246</td>
<td>5,090</td>
</tr>
<tr>
<td>GRAND TOTAL STUDENTS</td>
<td></td>
<td>9,756</td>
<td>9,787</td>
<td>9,626</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STUDENT PARTICIPATIONS</th>
<th></th>
<th>1986-87</th>
<th>1985-86</th>
<th>1984-85</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Includes Multiple</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity Duplication)</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. PHYSICAL EDUCATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Registrations</td>
<td>7,004</td>
<td>6,512</td>
<td>6,589</td>
<td></td>
</tr>
<tr>
<td>(Undergrad)</td>
<td>(5,672)</td>
<td>(5,324)</td>
<td>(5,298)</td>
<td></td>
</tr>
<tr>
<td>(Grad)</td>
<td>(940)</td>
<td>(957)</td>
<td>(909)</td>
<td></td>
</tr>
<tr>
<td>(Staff)</td>
<td>(392)</td>
<td>(231)</td>
<td>(382)</td>
<td></td>
</tr>
<tr>
<td>2. INTRAMURALS (M/W &amp; COED)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programs</td>
<td>22</td>
<td>21</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Teams</td>
<td>1,015</td>
<td>1,077</td>
<td>1,180</td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td>10,129</td>
<td>10,779</td>
<td>11,779</td>
<td></td>
</tr>
<tr>
<td>3. CLUBS</td>
<td>34</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td>1,076</td>
<td>1,052</td>
<td>985</td>
<td></td>
</tr>
<tr>
<td>4. INTERCOLLEGIATES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women's Programs</td>
<td>12</td>
<td>12</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>- Student Participants</td>
<td>251</td>
<td>211</td>
<td>205</td>
<td></td>
</tr>
<tr>
<td>- Varsity Letter Awards</td>
<td>135</td>
<td>142</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Men's Programs</td>
<td>24</td>
<td>24</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>- Student Participants</td>
<td>617</td>
<td>582</td>
<td>604</td>
<td></td>
</tr>
<tr>
<td>- Varsity Letter Awards</td>
<td>317</td>
<td>330</td>
<td>321</td>
<td></td>
</tr>
</tbody>
</table>

Report Year
EXHIBIT II

MIT DEPARTMENT OF ATHLETICS
FIVE YEAR LONG TERM STRATEGIC OBJECTIVES

FUNDAMENTAL MISSION
- To provide a high quality student-oriented physical education, recreation and athletic program that emphasizes participation and adapts to important trends. To enhance the MIT human environment for the entire MIT Community.

LONG RANGE (FIVE YEAR) OBJECTIVES
- Recruit and hire high quality people. Evaluate and develop their professional skills and personal/career paths. Improve minority faculty/staff representation.

- Continue to carefully manage and selectively adjust offerings for one of the largest percent participation programs in the United States in intramurals, club offerings, intercollegiate teams and general recreation opportunities; adapt to changing undergraduate profile (more women; less men).

- Stress the relevance and quality of physical education programs in the MIT educational context and the student community.

- Support and develop technology-aided health fitness; gradually expand campus-wide health fitness individual testing and education programs; encourage joint projects with Medical Department.

- Develop external resources for improvement of existing facilities. Plan and promote implementation of Phase III new facilities, artificial field surfaces and needed renovations.

- Gradually consolidate responsibility for all outside maintenance and building services associated with athletic programs.

- Reorganize office space and work locations for improved efficiency and cooperation within the Department.
EXHIBIT III

MIT DEPARTMENT OF ATHLETICS

Current Program Priorities
FY 1986-87

1. Introduce new communications and planning systems to improve operating efficiencies and the administration/coach partnerships; consolidate 36 sport intercollegiate program; improve personnel evaluation systems.

2. Implement leadership reorganization.

3. Recruit and hire minority faculty/staff.

4. Complete review of Athletic Department tenure system and decide future structure.

5. Manage existing facilities on a cost efficient basis.

6. Plan new projects on a priority basis; install Area A artificial surface; redress space inequities for women; improve opportunities for intercollegiate weight training.

7. Improve quality and relevance of Physical Education course offerings; support the P/E leadership in professional staff training and staff evaluations; reexamine philosophy and practice of non-course credit.

8. Implement jointly with Medical a campus-wide health fitness testing program; initiate other joint health education projects.

9. Transfer Physical Plant field maintenance personnel to Athletic Department.

10. Consolidate gains in graduate student participation in club and intramural programs; increase club sport budget.

11. Improve communication with MIT student body.

12. Support already close relationship with Admissions Office to sustain high quality of MIT matriculants; strengthen MIT athletic image and public relations impact of MIT "Athletic Excellence".
This past year was marked by major changes in the News Office, by the introduction of computers and electronic publishing throughout the Campus Information Services, and by new activities in support of MIT's equal opportunity objectives.

In the News Office, a new era was ushered in with the appointment of Kenneth D. Campbell, who has just completed his first year as Director of that office. Under his leadership, and with the contributions of the entire News Office staff, MIT has become much more visible in the national media; we have taken a much more active and strategic stance vis a vis the media on major issues and Institute priorities; and Tech Talk has become a more lively publication, reporting on events and issues.

Throughout the Campus Information Services, computers and electronic publishing took a major leap forward. The News Office will have a networked computer/word processing system for production of Tech Talk, news releases, and communication with sources of news and information throughout the Institute. The International Visitor's Office will now have its records on computer, with a data base in a form that will permit more efficient operation of the office as well as rapid response to requests for many different kinds of reports. The Communications Office will, in the coming year, use electronic publishing to update, typeset, and lay out the course catalogue as well as other publications. Design Services will use a computer and laser printer system as a design and typesetting tool.

Activities in support of MIT's equal opportunity goals this past year included, in addition to meeting our own hiring goals: participation in preparing and disseminating the Report on the Racial Climate at MIT and development of a national media network and news releases targeted at minority (primarily black) media.

At year's end, we bid formal farewell to Robert M. Byers as he retired from the Institute. Fortunately, he has agreed to work with us during the coming year as a part-time consultant on writing projects for the President, a service that he performed with extraordinary talent and effectiveness during the past year.

In the year to come, we can anticipate increasing activity and responsibilities relating to the Immigration Reform and Control Act, particularly the provisions relating to verification of visa status for all who work here. This will have a major impact on hiring and record-keeping practices throughout the Institute. And, as in the year just past, the Campaign for the Future will require major involvement on the part of the News Office, the Information Center, and Design Services, as we seek to make the best possible case for support of MIT among our alumni, friends, and the public at large.

KATHRYN W. LOMBARDI

COMMUNICATIONS OFFICE

The Communications Office continued to make advances this year toward the establishment of a workable "electronic publishing program" for the course catalogue and other Institute publications.

After nearly a year of steady research into the office's needs and the applications offered by various computer and software systems, a decision was made to purchase a VAXstation 2000 computer workstation from Digital Equipment Corporation. This computer has far greater processing power and memory capacity than a conventional PC. When coupled with advanced publishing software from Interleaf of Cambridge, MA, the office will be able to maintain and update the databases of cyclical publications and then print out formatted pages from a high-quality laser printer, or produce these pages from a "back end unit" of a conventional typesetting system. Eventually, this should eliminate the need for hiring typesetters to go through the rounds of copy updates and format coding required for all office publications. In the case of the course catalogue alone, cost savings should be quite substantial.

In addition, the VAX has the ability to communicate with existing mainframes on campus, which will enable us to exchange publication copy electronically. In the not too distant future, it is hoped that portions of the course catalogue database can be used to format smaller informational pieces for departments that would like to send to prospective students detailed curricula and subject material, but not the entire catalogue.
By year's end, we hope to have not only the Courses and Degree Programs catalogue database on line, but Policies and Procedures, departmental single-sheet descriptions, portions of the Student Telephone Directory, and the Summer Session Catalogue.

In the publications area itself, the office was busy last fall producing large and small editions of the Report of the Treasurer and similar editions of the Report of the President, the small version appearing in the 12 November 1986 edition of Tech Talk. The office also produced for the 19 November issue of Tech Talk the annual listing of Committees of the Institute.

This year, the Student Telephone Directory took on a new look, with typeset student name and number copy, a four-color cover, and a small "yellow pages" advertising section. Response to the new version has been favorable. The office is switching directory publishing companies this year with the hope of a bigger advertising section and press run. Once again, the cost of typesetting, printing, paper, and binding will be paid for by the publishing company with revenues generated from the sale of ad space.

During the winter, the office produced a new edition of the Summer Session Catalogue. The money saved by electronically transmitting copy to the typesetter from a floppy diskette was used to print a more interesting cover. For all future office publications, it is hoped that similar savings can be used to enhance existing features.

During the spring, all manuscript copy updating for the Courses and Degree Programs catalogue was done in the office on floppy diskettes, saving the Institute nearly $5,000.00 in typesetting costs.

Other projects this year included production of the Walk Around MIT and Welcome to MIT brochures for the Admissions Office and academic departments. Production for both these pieces is still in progress, but should be ready by late July.

Personnel changes

Helen M. Blue, who was hired as Editor and Production Manager in May 1986, left at the end of June to relocate to the West Coast. Nancy A. Ferrari, formerly Administrative Staff Assistant in the office, was offered the position and will start in early July. We look forward to an exciting and productive year.

MARK WILSON
DESIGN SERVICES

The Office of Design Services continues to support the communications efforts of MIT by designing and managing the production of publications for departments and offices throughout the Institute. Among the areas receiving major assistance from the office during the past year were the Corporation, Committee on the Visual Arts, Resource Development, the School of Engineering, the Sloan School of Management, the Special Summer Programs, and a wide range of special events and conferences coordinated by the Information Center. Included among these were the dedication of the Ronald E. McNair Building and the 15th Anniversary of the Council for the Arts.

Overall the office undertook 253 graphic design and publishing projects in 1986-1987.

In 1986 Ralph Coburn received an Award for Excellence from the Art Museum Association of America for the "Artists and Architects Collaborate: Designing for the Wiesner Building" booklet.

Jacqueline Casey was invited to be an Honorary Committee Member for the 75th Anniversary celebration of the Art Institute of Boston. Her work was shown in the exhibitions: UNESCO's World's Most Memorable Posters at the Grand Palais in Paris, "Images for Survival Peace Posters" in the MIT Compton Gallery, the Type Director's Show, New York, and the International Invitational Poster Exhibition, Colorado State University. Among the past year's publications in which her work appears are "Graphis Posters 78," Switzerland and Typography 7, New York. Two upcoming books scheduled for 1987 publication are "Basic Layout and Design," Gill Elsbury, Phaidon UK, and "American Typography," Rob Carter, Van Nostrand, Reinhold Company.

JACQUELINE S. CASEY
INFORMATION CENTER

This past year has again been a year of active participation and goal setting for providing service and information in print, in person, and over the telephone to the MIT community and to visitors; assisting the international faculty and staff; and coordinating Institute dedications, meetings, and conferences.
Public Relations and Information Services

During the past year, the Center continued to be a clearinghouse for mail addressed to MIT; to maintain the official Institute mailing lists; answer and direct to other offices telephone and office inquiries from the public and the MIT Community; distribute over 43,000 pamphlets, brochures, guides, and catalogues; maintain records and publish a Tech Talk supplement describing and listing the memberships of the faculty and presidential committees. The tour guide captain David Kramer, '88, who was an excellent guide himself, arranged and supervised tours for some 8,400 visitors by 17 of our student staff. Carla Kapikian, '88, and Laura Malley, '87, were full-time tour guides during the summer months; they received many compliments and rounds of applause upon completing their tours.

Arrangements were made for 10 delegates and 3 greetings to be sent to other universities' inaugural ceremonies.

International Visitors Office

Visa applications were numerous, with many involving special expertise and fine tuning to solve individual problems. A computer has been obtained and the manual record-keeping system is being converted into a data base. Statistics for international staff and faculty should be available at the end of the summer when the manual record-keeping system has been converted into a data base. A wide range of reports will be available when the program is completed.

Registration of new arrivals was developed into a weekly orientation/registration session, eliminating the time consuming and repetitive one-on-one registration. The International Visitors Office staff ran an immigration workshop for MIT administrators in March, sponsored a tax workshop during IAP, and Virginia Lyons made a presentation on "Hiring Foreign Personnel under the New Immigration Law" as part of an Industrial Liaison Program seminar in May.

Public and Institute awareness of immigration issues grew as the Immigration Reform and Control Act (ICRA) became a regular feature on the front page of major newspapers across the country. A decentralized verification system has been set up with both personnel officers and department administrative officers handling the verification form. Instructions and information about the non-immigrant visa categories and documents have been and are being prepared by the International Visitors Office.

Dean for Student Affairs Shirley McBay convened a group of individuals interested in the quality of life of international students and scholars at MIT. The group will be reviewing various services and programs for the international community, and expects to make its recommendation during the coming academic year. Virginia Lyons completed her tenure as Executive Officer for the Committee on International Institutional Commitments at the end of June, after serving six years with the Committee.

Special Events and Conferences

The Conferences Services Office managed the logistical arrangements of 15 conferences, which brought over 5,000 visitors to campus. The office also coordinated the logistics for 8 summer courses sponsored by the Center for Real Estate Development. The Massachusetts Special Olympics returned to MIT for their summer Games in June, which will be an annual event. These games brought over 3,000 people to the campus, including over 1,000 athletes.

In addition to conference coordination, this office assisted the Admissions Office with the Campus Preview and Minority Spring Weekend Programs. Arrangements were also made for over 90 on-campus presentations in conjunction with the Office of Career Services and Preprofessional Advising.

Mrs. Fitzgerald was involved in the planning of Student Center renovations as a member of the Project Team; construction was scheduled to begin 1 August 1987 and continue for the next fiscal year.

The Director coordinated various special events including the dedication of the Ronald McNair Building and the Commencement exercises, which this year were held on a brilliant sunny day. One thousand eight hundred nine students received 1,984 degrees while over 8,000 families and guests observed the ceremony. A festive and happy celebration followed the Exercises, with several thousand guests gathering at the President's Reception in the areas surrounding McDermott Court. It was a happy occasion for all.

This report would not be complete without a special salute to all the staff who, working as a team, combine duty and service with a sense of humor. All of them play a special and important role to the Institute and the Information Center: Virginia Lyons, whose guidance and knowledge on visa and immigration regulations has made her one of the most creditable and knowledgeable university immigration professionals in the country; Gayle Fitzgerald, who continues to develop and strengthen the conferences to a level far exceeding her charge; Lillian Whelpley, who conscientiously and very
ably handles all H-1 visas; including the streamlining, updating, and production of reports on faculty surveys for the Institute committees; Kathleen Barrett, whose knowledge, kindness, and sense of service have carried all of us through many a strenuous day; Terri Priest, who efficiently organizes tours and meetings for short-term visitors to the Institute and, in addition to other duties, oversees the tour guides; and Donald Ferland, whose support in assisting the director and the Information Center is invaluable. A special welcome to new members of the Information Center: Marie Seamon as assistant coordinator of Conference Services and Vera Mayorga in the Conference Services Office, Barbara Potter and Tara Dowling in the International Visitors Office, and Douglas O'Roark, '89, who is converting the manual recordkeeping into a data base for the International Visitors Office. In addition, our thanks go to those who have left us: Elsie Bennett Kappler to join the MIT Office of Major Gifts, Lisa Bartolet to attend graduate school, Virginia Silverman to enjoy motherhood, Martha Lyman, '88, who worked during the summer months in the International Visitors Office, and Mary Clark who obliged us all by leaving California for several months to fill in for Virginia Lyons while she was on maternity leave.

MARY L. MORRISSEY

NEWS OFFICE

Some spectacular news events and active MIT News Office outreach to the national news media raised the profile of MIT in the news in 1986-87. Foremost among these events was the Daedalus Project, encompassing mythology, students building an advanced aeronautical machine, and marathon athletic prowess -- an activity that has captured the imagination and attention of the news media throughout the nation and world to an unprecedented degree in recent MIT experience.

The top 10 news stories from MIT, in terms of repeated interest by the national media, were:

1. Project Daedalus, which set distance records for human-powered aircraft.
2. Review of the curriculum and the undergraduate experience.
3. Appointment of Lester Thurow as Dean of the Sloan School of Management.
4. Admission of a record number of women in the Class of 1990.
5. The university's actions on the racial climate at MIT.
6. The dedication of the Ronald E. McNair Building.
7. The development of a computer-generated three-dimensional holographic image by Professor Steven Benton.
8. The MIT Museum's lead role in the Bauhaus exhibition.
9. Acknowledgment by leading economists, analysts, columnists and government officials that MIT serves as an economic engine for the economies of Massachusetts, New England and the United States.
10. The award of the Pulitzer Prize in music to Professor John Harbison.

A score more topics, principally the product of MIT research, also received wide attention in the nation's newspapers, radio and television, as well as in the scholarly journals of individual intellectual disciplines.

Strategic Actions

Some of the prominent coverage was the result of new strategic activities by the News Office. These new initiatives included: more frequent news interviews with President Paul E. Gray and more articles written by him for publication; targeted media campaigns on admissions issues, curriculum review, the racial climate at MIT, and selected research activities; development of a new mailing list of black-owned news media; and "hometowning" news about MIT graduates. Development of a new mailing list of black-owned news media proved its value when several major newspapers in America's black communities devoted more than a third of their front pages to a story and photograph, sent in advance of the event, of MIT's dedication of the Ronald E. McNair Building.

Special News Office attention focused during the year on the growing role of women students at MIT, and the review of the undergraduate curriculum. Both received prominent coverage in the nation's most influential newspaper, The New York Times, including front page coverage on Commencement Day 1987 of the humanities curriculum changes. The News Office's role in approving the use of the name
of MIT in advertising and publicity provided an opportunity to help write a portion of a television drama. This resulted in an estimated 7.7 million people, principally teenagers, seeing MIT favorably through the eyes of a prospective woman student and her mother in the February ABC Afternoon Special drama, "Supermom's Daughter." The supermom, a television news anchor, read a news item about women in science, featuring the fact that 38 percent of MIT's Class of 1990 were women.

Part of the News Office strategy in assisting the goals of the Admissions Office is to make sure that more people are aware that MIT has a local connection: the young man or woman who just graduated from MIT. The tedious task of preparing individualized news releases for every community with an MIT graduate is a significant technical and clerical achievement that tells hundreds of communities and thousands of prospective students that someone in their community is a potential MIT role model for them.

A major initiative was the forthright handling of the news media's interest in MIT's in-depth study of the campus racial climate, a topic that subsequently became a major issue on other campuses during the year. President Gray's bold and blunt approach to a very sensitive issue and a very frank report by the Minority Student Interest Group, won respect for MIT's approach. News coverage was tough but fair in The Boston Globe, the wire services, National Public Radio, the CBS Morning News, The Wall Street Journal and other publications.

A follow-up story, concerning Dean Shirley McBay's speech in Washington on opportunities for minorities, was drawn to the attention of Washington Post columnist William Raspberry, who wrote about it in a column distributed to more than 170 newspapers.

Reporting on research is sometimes difficult to plan in advance. The holograph is an interesting example. The story in the national press was broken by a reporter from USA Today. The News Office and MIT's Media Laboratory quickly organized a news conference and sent advance word on it to the news media through a public relations newswire. The news conference was attended by 20 reporters, and with Associated Press and the United Press International providing detailed reports and photographs, U.S. newspapers with a combined circulation of more than 20 million carried stories on it.

Tech Talk

The stronger emphasis this year on national news-making ran parallel with increasingly lively coverage of campus events and controversies in Tech Talk. Under the editorship of Joanne Miller, Tech Talk was enlivened by Paulette Boudreaux's features and news stories (one of which -- on Morton Thiokol/Challenger engineer Roger Boisjoly -- was picked up by The New York Times); Charlie Ball's "Here and There" column of people and events; China Altman's coverage of the arts; the photographs of Donna Coveney, Barry Hetherington and Paula Lerner; frequent faculty/administration contributions to the opinion space on the back page; and news articles by Charlie Ball, Bob Dilorio, Ken Campbell and Joanne Miller, plus various contributing writers from around the campus. Joanne Miller also did the initial administration of the photography services project to other MIT offices.

Staff, Computers and Space

The year saw changes in staff, in organization of tasks, in development of a new plan for a computer network system, creation of a new darkroom, and in the planning of the office space in Room 111 of the Pratt Building (better known as 5-111).

A number of members who made significant contributions to the News Office moved on to other positions during year. Those who left us included Paula Lerner, interim photographer; Sharon Davis, Tech Talk reporter and secretary; Eugene deMesne, senior secretary; Norman Chen, '87, part-time computer consultant on the Condor data base management system; and Karen Gold, '87, part-time arts assistant.

Those who joined us included Paulette Boudreaux, Assistant Editor of Tech Talk and formerly of the Boston College News Office; Donna Coveney, Assistant Director/Photojournalist, formerly photo editor and chief photojournalist for The Beverly Times; L. Barry Hetherington, part-time photographer for contract photography services to other MIT offices; Joy King, administrative secretary, formerly with the Office of the Dean for Student Affairs; and Mary Thompson, receptionist, formerly with a private firm in Cambridge.

A reorganization of the support staff saw Lynn Heinemann, senior secretary, take a new position as senior secretary-editorial in the three-person support staff.

A new computer networking system was developed with the assistance of Stephen Scarano of Information Services to provide a flexible system combining different hardware but permitting internal computer communication in the News Office. The system was on order at year end.
As the 1987 academic year closed, the News Office moved to temporary quarters to permit the summer renovation of the 5-111 offices, to create space for the hiring of two more staff writers in the 1988 academic year.

KENNETH D. CAMPBELL
Many trends in the economy threatened to make 1986-87 a difficult year for students entering the job market. It may have been a difficult year at some campuses, but at MIT the market held up well.

Notwithstanding lean times in many industries (oil, energy systems, semiconductors), slow growth in others (chemicals, computers, automobiles), corporate "downsizing", mergers, and a leveling-off in the growth of defense spending, more companies and government agencies came recruiting than the year before. A total of 423 employers made one or more visits, compared with 395 in 1985-86. The total in 1984-85 was slightly higher, 431. The discipline most often requested was electrical engineering, followed closely by computer science. Mechanical engineering was requested two-thirds as often as electrical engineering; chemical engineering, materials science and engineering, and aeronautics and astronautics were requested one-third as often.

Students were skittish about interviewing with companies whose business prospects looked uncertain, and some companies canceled visits for lack of sign-ups, but by year end some 10,500 interviews had been conducted under the auspices of the Office, compared with a little under 9,000 in 1985-86 and a little over that number in 1984-85. If interviews are the measure, we have never had a busier year. The number of interviews this year was nearly double the total ten years ago, and more than three times the traffic fifteen years ago.

Students interested in the aerospace industry were particularly assiduous in having interviews. Only a dozen companies are major contractors for the design of aircraft and space vehicles and on days when the interview schedules were posted students waited in line before the Office opened to make sure they got an appointment.

Other industries attracting heavy traffic were the investment industry and management consulting. Both industries have been booming, and both have shown a growing interest in the quantitative and analytic skills of technical graduates. The personal computer, more powerful every year, has put a tool in the hands of the business analyst which challenges his mathematical sophistication. At the same time the use of linked computers to handle financial transactions around the world has opened a Pandora's Box of options for the trader to analyze and exploit. This year the leading Wall Street firm of Salomon Brothers published a handsome recruiting brochure aimed specifically at technical graduates, including graduates with advanced degrees. McKinsey & Company, equally prominent in management consulting, decided this year to look for technical PhD's who could join the firm on the same terms as MBA's; for a number of years they and other consulting firms have been hiring graduating bachelors with technical backgrounds as junior analysts.

One reason for students' interest in finance and consulting is that they offer challenging jobs outside the laboratory. There is a significant "underground" of students in science and engineering - not readily visible because they are shy of telling faculty of their disaffection - who have found that technical work is not their greatest interest. They do not want to be "stuck in a laboratory", as many of them put it. Not a few are students with high grade point averages, students who have written admirable theses, PhD's and postdocs with a slew of papers to their name. They see manufacturing industry as offering them only technical work. They are not entirely right in this perception, but it is true that Wall Street and the management consulting firms show a greater willingness to use them in other roles. There is irony in this because in many cases the clients they will be concerned with as analysts and consultants will be manufacturing firms. The latter's failure to offer them a parallel opportunity in-house is the manufacturing sector's loss and, in these times when manufacturing's vitality is crucial to the health of the dollar, a loss to the economy.

Supporting the market for MIT talent in 1986-87 was the demand coming from new companies and from the new activities of old ones. Many companies went out of their way to emphasize their need for people. They included firms coming recruiting and firms contacting us by mail. This demand from new quarters made for an excellent year in alumni placement. We were able to help a significant number of alumni - among them many whose careers had been set back by the economy - find good new opportunities. Much of the credit for this is due to Marianne Ciarlo, who has made the most of a support staff position in which she has been responsible for looking after not only alumni interested in jobs but also students interested in study abroad. It was with great pleasure that we were able to promote her to a full staff position in Hay.

Our Practical Experience Program aimed at helping underrepresented minority students find professional-level summer jobs also had a good first year. Ann Davis Shaw, who joined us a year ago to manage the program, has reached out effectively to the minority community on campus, encouraging more minority
students to use the Office, and has enabled us to strengthen materially our collaboration with employers' affirmative action efforts. What we can achieve at MIT has a great bearing on the success of their programs. MIT ranks fifth among predominantly white schools in the number of black students receiving bachelor's degrees in engineering.

If the queasiness of the economy was not reflected in the level of recruiting activity, it did show itself in the number of offers reported and in salaries. Matching the situation at other campuses, the number of offers reported was generally down from the year before. For example, seniors in electrical engineering and computer science reported a quarter less offers. There were also fewer offers to master's candidates in aeronautics and astronautics and in chemical engineering. On the other hand there were more offers to seniors in management.

Salaries themselves hardly moved from the year before. For example, salaries offered to bachelors in electrical engineering were up less than three percent (to a median of $31,020); offers to bachelors in chemical engineering were up less than two percent (to $30,480); offers to PhD physicists were up one percent (to $45,000). The highest offers were to PhD's in electrical engineering, up 6.5 percent to $51,000. It was a good year for students with computer skills. Offers to seniors in computer science (up over four percent to $31,320) exceeded for the first time offers to seniors in electrical engineering, and the highest offer reported by any technical student ($70,000) was to a PhD in computer science.

What MIT students want in their careers

We sent a questionnaire to students graduating in 1985-86 in which we asked them to rate the importance on a four-point scale of sixteen things that might be important to them in their careers. One item was rated "essential" or "very important" by nearly ninety per cent of the students in every School at the Institute: this was the opportunity to implement their creative ideas. Two-thirds or more gave equal importance to variety of work, and independence in their work. Fourth in terms of the number who gave it a high rating was being an expert. The importance attached to this, however, did not go hand in hand with the importance of being able to do research. While 87 percent or more of the PhD's in science and engineering rated this essential or very important, it was the view of only 42 percent of the seniors in engineering, only 36 percent of the students (undergraduate and graduate) in architecture and planning, and just 14 percent of the students in management.

There was similar diversity in the degree of importance attached to the opportunity of becoming a top manager, and to starting one's own business. While 71 percent of the management graduates, not altogether surprisingly, rated it essential or very important that they have the opportunity to become a top manager, less than twenty percent of the students in science thought this so important. On the other hand 42 percent of the seniors in engineering and 41 percent of the students in architecture and planning were one with the management students in wanting a shot at top management. Their eagerness to manage appears all the stronger if one includes those interested in starting or running their own business. Fifty-three per cent of the seniors in engineering (49 percent of the masters) and 66 percent of the students in architecture and planning rated it essential or very important that they have the opportunity to become a top manager or that they have their own business.

Another interesting divergence showed in the willingness to engage in defense work. For the most part defense work did not greatly trouble students in engineering, but 40 percent of the seniors in science and 48 percent of the PhD's in science deemed it essential or very important that their work not be associated with defense. One department in engineering expressed themselves in much the same way as the scientists - the electrical engineers, 45 percent of whom were equally averse to working in defense.

Roughly half the class returned the questionnaire. The results have obvious significance for recruiters, but also have implications for the Institute's various curriculum committees. A paper is available containing the results in detail.

Medical School

The number of MIT candidates to medical school declined this year, matching a decline in the nation at large. There were a total of 112, compared with 123 in 1985-86. They included 65 seniors, 1 graduate student, and 46 alumni. As of the first of July 54 of the seniors had been accepted (83 percent), the graduate student had been accepted, and 37 of the alumni (80 percent). The overall acceptance rate at this preliminary stage was 82 percent. Every year a number of candidates get accepted in July and August, so the final acceptance rate is likely to be higher.

ROBERT K. WEATHERALL
For the Medical Department, 1986-1987 will be remembered as a regrouping year. New leadership is in place in the persons of Dr. Arnold N. Weinberg, Medical Director and Department Head, and Linda L. Rounds, Executive Director. The new Medical Director learned a great deal about the Department and the Institute from experienced colleagues like Ms. Rounds and Associate Medical Director, Dr. Michael A. Kane. Dr. Kane had worn two hats for almost a year and left the combined Acting Medical Director and Executive Director jobs in fine shape — a real tribute to his managerial, leadership and human skills as well as bottomless energy! Dr. Kane returned to his former duties on November 1, 1986, as Associate Medical Director, Chairman of the Credentials Committee, physician and master consultant to the new leadership.

A number of initiatives and continuing tasks have occupied this past academic year. Under the leadership of Dr. Bruce J. Biller, we are preparing for the return visit of the Joint Commission on Accreditation of Hospitals (JCAH) three years after their last visit and approval of our Inpatient and Ambulatory facility. This preparation involves a huge effort that gives the Department a unique opportunity to examine its programs and practices, rules and regulations, human resources and physical plant features. We look forward to another unqualified three year endorsement after this rigorous JCAH survey.

Mandated by the Commonwealth of Massachusetts, a new law (Chapter 351) will attempt to guarantee patient rights and care while defining expectations for professional competence, credentialing and behavior. A program has been developed and is in place just as the academic year concludes. Dr. Stephen J. Healey, Chief of Surgery, will serve as coordinator for the first years of this activity, called the Patient Care Assessment Program.

Our efforts to develop new health care benefits continue, under the direction of Dr. J. Christian Kryder, Physician and Special Assistant to the Executive Director. A major initiative under study is the planning for a Preferred Provider Organization (PPO) as an offshoot of the MIT Health Plan. Decisions in this area are important to the vitality of our Plan in short and long term planning. For details about the MIT Health Plan see the appropriate following section.

After several years in study, the Medical Department made a firm decision to bring routine laboratory services in-house, an effort that we anticipate will guarantee continued high quality testing, efficient and prompt information transmission and economies. Outside consultants have provided appropriate inputs to a Medical Department team that now is working on a final plan after reviewing proposals and interviewing potential clinical pathology and laboratory support groups. In the interim period, services are primarily being provided by an outside BioScience testing laboratory.

The primary medical care providers of the Department have been meeting as a group to discuss and eventually implement how we can improve continuity in patient care. We have agreed to make changes that will decrease fragmentation of coverage in the Inpatient Service and the process is extending broadly to include review of ambulatory practices, Off-Hours Clinic coverage and communication with physicians and our patients being cared for at outside hospitals.

Student health and health education have been areas of continuing discussion and planning. The combined efforts and resources of the Medical Department, the Office of the Dean of Student Affairs and the Health Education Service has resulted in planned activities to orient students and their families to health issues faced by all young people. A committee is at work studying means of communicating with students about health issues, including sexually transmitted diseases, AIDS, eating disorders, etc. We are arranging for convenient health aid dispensers for the living units (aspirin, antihistamines, cold remedies, safer sex materials like condoms, etc.) as well as an area for information brochures on a variety of health subjects.

Under the able direction of Dr. Mark A. Goldstein, Chief of Student Health Services, we are instituting a program of assigning specific physicians to half of the incoming Freshmen and 1st Year Graduate Students. These individuals will be compared with the other half of each group, that will use the medical facilities as needed without specific prior physician contact or assignment. Entry and exit questionnaires are being developed and we will study patterns of utilization, attitudes and effectiveness of care for both groups.

The Medical Department is energetically involved in a variety of educational activities at MIT, both informal and formal in design. During Independent Activities Period in January, members of the Department provided a number of programs for students, faculty and staff. Informal meetings were held in living areas to discuss topics of student choice. Members of the Department teach Introduction to Clinical Medicine to candidates for Biotechnology degrees in the Health Science and Technology (HST) program. Discussions are now underway to offer introductory clinical experience for Harvard medical students in the HST program.
Improvements in the Department’s medical services continued during the past year. Nighttime nurse practitioner coverage in the Inpatient Unit became a reality and has helped us care for complex patients. Ultraviolet light therapy is in place, echocardiography is available and selected screening ultrasonic studies for pregnant women will soon be offered in the Department. We are studying hangups in certain areas that lead to significant waits for appointments and plan changes that will ease that frustration for patients and providers. We will continue to devote significant time to lowering barriers and shortening the waiting time for patients in sensitive areas. This will be accomplished in part by asking our primary care physician group to assume ongoing responsibility for patients after consultation with subspecialists for selected problems.

The following selected sections present information on a number of specific areas and personnel changes effecting our overall involvement with the MIT community.

Staff Changes

Administrative and other professional staff personnel resignations, retirements and changes in title occurred during the period of June 20, 1986 through June 30, 1987:

--- APPOINTMENTS ---

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles Billings</td>
<td>Industrial Hygiene Engineer</td>
</tr>
<tr>
<td>Theresa Connolly</td>
<td>Inpatient Nurse</td>
</tr>
<tr>
<td>Alan Ducatman</td>
<td>Chief, Environmental Medical Service</td>
</tr>
<tr>
<td>Sharon Edwards</td>
<td>Dental Hygienist</td>
</tr>
<tr>
<td>Mario Fresina</td>
<td>Industrial Hygiene Technologist</td>
</tr>
<tr>
<td>Dirk Greineder</td>
<td>Allergist</td>
</tr>
<tr>
<td>Richard Hilliel</td>
<td>Otolaryngologist</td>
</tr>
<tr>
<td>Robert Kiskaddan</td>
<td>Otolaryngologist</td>
</tr>
<tr>
<td>Patricia Kravetz</td>
<td>Pharmacist</td>
</tr>
<tr>
<td>Thomas Lynch</td>
<td>Industrial Hygiene Technologist</td>
</tr>
<tr>
<td>Eva Lyons</td>
<td>Coordinator of Enrollment Services</td>
</tr>
<tr>
<td>Frederick McWilliams</td>
<td>Reactor Radiation Protection Officer</td>
</tr>
<tr>
<td>Mary Ramos</td>
<td>Nurse Practitioner</td>
</tr>
<tr>
<td>Patricia Reardon</td>
<td>Inpatient Nurse</td>
</tr>
<tr>
<td>Deborah Scott</td>
<td>Dermatologist</td>
</tr>
<tr>
<td>Margaret Stinson</td>
<td>Assistant Radiation Protection Officer</td>
</tr>
<tr>
<td>Julia Waldron</td>
<td>Nurse Practitioner</td>
</tr>
<tr>
<td>Arnold Weinberg</td>
<td>Medical Director</td>
</tr>
<tr>
<td>Matthew Weintraub</td>
<td>Surgeon</td>
</tr>
</tbody>
</table>

--- RESIGNATIONS ---

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheryl Birchette-Pierce</td>
<td>Physician</td>
</tr>
<tr>
<td>Murray Bolton</td>
<td>Assistant Radiation Protection Officer</td>
</tr>
<tr>
<td>Richard Chamberlin</td>
<td>Associate Director, Environmental Medical Service</td>
</tr>
<tr>
<td>Edward Dyer</td>
<td>Pediatrician</td>
</tr>
<tr>
<td>Joan Flewelling</td>
<td>Inpatient Nurse</td>
</tr>
<tr>
<td>William Franklin</td>
<td>Allergist</td>
</tr>
<tr>
<td>Edward Karalyn</td>
<td>Associate Radiation Protection Officer</td>
</tr>
<tr>
<td>Josiane Lederman</td>
<td>Dermatologist</td>
</tr>
<tr>
<td>Carolyn Leonard</td>
<td>Inpatient Nurse</td>
</tr>
<tr>
<td>John McKeigue</td>
<td>Otolaryngologist</td>
</tr>
<tr>
<td>Allan Oseroff</td>
<td>Dermatologist</td>
</tr>
<tr>
<td>Karen Paulino</td>
<td>Coordinator of Enrollment Services</td>
</tr>
<tr>
<td>George Petievich</td>
<td>Assistant Director for Operations and Systems</td>
</tr>
<tr>
<td>Willard Putnam</td>
<td>Physician</td>
</tr>
<tr>
<td>Jacob Rice</td>
<td>Ophthalmologist</td>
</tr>
<tr>
<td>Wade Rockwood</td>
<td>Psychiatrist</td>
</tr>
<tr>
<td>Melvin Rodman</td>
<td>Medical Director</td>
</tr>
<tr>
<td>Robert Tilley</td>
<td>Dermatologist</td>
</tr>
<tr>
<td>Charles Tracy</td>
<td>Dentist</td>
</tr>
</tbody>
</table>

Nursing Service

The Nursing Service under the able direction of Ms. Deborah Dacus has continued to provide outstanding care for Medical Department patients in the ambulatory, inpatient and walk-in emergency service areas. Through a change in staffing patterns our objective of 24-hour coverage in the Off-Hours Clinic has been achieved. The Inpatient Unit, ably directed by Ms. Maureen Dickey, has diligently worked to increase the service's ability to care for a wide variety of patients in a competent and thoughtful manner. During the year, many letters in praise of nursing care in the Inpatient Unit were received by the Medical Director.

In addition to patient care, the nurses' continuing education program has been thriving under the able direction of Ms. Janice McDonough. A noteworthy new effort was a full-day program offered to the community at large and with 107 participants registering eventually. In addition, the Nursing Service participated in the IAP effort with 5 programs, including a well attended Family Health Fair. The Nursing Service is an enormous asset of the Medical Department in its humane efforts to care for patients.
Social Work Service

The Social Work Service is a valuable asset for both the Medical Department and the MIT community. With more complex and older patients the demands for discharge planning services have increased. This has been compounded by the new requirements of the Board of Registration in Medicine making it mandatory for every inpatient to have discharge planning initiated upon admission to an inpatient service like ours. An additional social worker will be added to the staff to ease the burdens in this critical activity. As an adjunct to discharge planning expertise, members of the Service participated in Inservice training conducted by a senior discharge planner social worker from Massachusetts General Hospital. In addition to serving on many committees in the Department, the Social Work Service has continued to play an important role in the life of the MIT community with involvements with supervisors, deans, minority students, administrators, campus police, personnel officers, both directly and through the Institute Personal Assistance Program. The Social Work Service continues to provide expertise in dealing with problems of alcohol and drug abuse, both for individuals as well as for close members of families with addicted members.

Health Education Service

This was the first full year of activity for the new head of the Service, Ms. Janet Van Ness, who provided great energy and leadership. Expansion and initiation of activities with health-promoting objectives led to 3400 individuals (over 50% greater than the prior year) directly reached by health education programs and services. Progress has been made in developing ongoing services and programs for students in health education through activities during IAP month, visits to living units, provision of a variety of programs and brochures and contribution to the ongoing Student Health Task Force of the Department. Other activities have included individual consultation, program development at Draper and Lincoln Laboratories in nutrition and smoking cessation, expansion of the car seat loan program (141 families took advantage of this this year), development of the lending library as a resource center in health education (visited by at least 1200 people this past year) and the acquisition of a state of the art videocassette recorder and monitor to complement other health promotion efforts of the Service.

MIT Health Plan

Like other managed-care health programs, MIT is clearly feeling the competition for membership. After an active open enrollment period, membership grew to just over 8500 individuals. New strategies are under consideration to expand membership the most promising of which is a Preferred Provider Organization (PPO) option which would be responsive to concerns voiced by many. The added flexibility of a PPO includes the options to use other high quality health care providers and hospital facilities convenient to people who work at MIT but live a distance from Cambridge. We expect to finalize a plan for offering a PPO and will consider phasing the program in by January 1, 1989 at the latest. The Plan’s financial status continues to be affected in a positive way through our carefully managed utilization of acute hospital care. Our efficient outstanding Inpatient Unit has permitted us to bring more patients back to MIT after fewer days in impersonal, larger hospitals where surgical and other therapies are initiated.

Environmental Medical Service

Under the energetic and able direction of Dr. Alan Ducatman, EMS has markedly increased the scope of its services during the past year. A major activity pertains to asbestos in the workplace. In addition, EMS increased its traditional responsiveness to community concerns such as odors, drinking water purity, indoor air complaints, insect and other vermin exposures. Each of the three divisions of EMS has addressed its area of responsibility by programs of teaching, facility engineering and personal protection devices to reduce exposures. Off-campus and affiliated facilities have received increased attention and departments affected by environmental regulations have called on EMS to help in dealing with those regulations. I can’t conclude this brief summary without lifting in toto the final paragraph from Dr. Ducatman’s report, and I quote: “EMS does much for the Institute but can do more. An oncoming challenge will be to add our resources to course work so that MIT graduates in engineering, science programs, technology and policy and especially business have the knowledge to compete with their colleagues in confined competitive benefits where they previously learned only about risk.”

Direct Patient Care Services - A Summary

1. Ambulatory Management Activities: The Off-Hours Clinic serves the community between 5:00 p.m. and 8:30 a.m. weekdays and throughout the weekends. Services for 6000 visits and an additional 8000 to 10,000 telephone triage calls have been handled by the addition of a nurse practitioner to the nurse/physician team staffing the Clinic.

2. Dental Service: The Dental Service, under the able leadership of Dr. Cynthia Stevens, saw approximately 10% more patients in 1986-87 than 1985-86. In addition to the variety of services provided, a health education program has been in place and thriving. Quality Assurance programs have led to evaluating patient care and record keeping that help in planning prospectively for continued excellence in the future.
3. Pediatric Service: Dr. Barbara O'Pray, Chief of Pediatrics, reports that the Service had an increase of 60 deliveries leading to a total of 190 newborn babies to care for, in addition to babies of student families delivered by outside obstetricians. Medical education sessions continue with weekly conference for medical students in the Adolescent Unit at Children's Hospital and in the Introduction to Clinical Medicine course at Harvard Medical School.

4. Psychiatric Service: Dr. Merton Kahne reports that the major preoccupation of the Psychiatric Service has been in hospitalizations for emotional difficulties. Although the number of admissions to mental hospitals remained approximately the same, the number of patient days increased and approximately one third of these admissions to outside hospitals were for alcohol or drug related problems. Students represented only 20% of hospitalizations. In spite of the retirement of Dr. Wade Rockwood, the number of ambulatory visits remained approximately the same. The Psychiatric Service is in the process of evaluating its various methods of providing services to individuals and groups. As in the past, members of the Psychiatric Service have been invaluable counselors to offices of administration and student and faculty committees at MIT. In addition, individuals have been involved in education and counseling efforts beyond the Medical Department walls.

5. Ob/Gyn Service: The Service continues to increase its activities with many student families coming for obstetrical care. In addition, family planning, routine and complex gynecological examinations have also been heavily utilized by the MIT community. Primary and secondary infertility issues, counseling for various obstetrical problems and breast feeding difficulties have been areas of increased activity. A recent study of the Ob/Gyn Service has lead to a number of suggestions which will improve efficiencies in the care of patients.

6. Student Health Service: Under Dr. Mark Goldstein's able direction, the Student Health Service has continued to thrive. Surveillance of student immunization has been completed and an audit of records indicates compliance of almost 100%. Incomplete student medical reports have been managed for the first time by Medical Department physician visits rather than using non-professional technical personnel to complete these examinations. Stronger liaison with the Dean's Office and with the Athletic Department has been accomplished, with meetings and timely interventions around issues such as confidentiality, drug testing, and HIV testing. The primary physician program is being developed and will be put into place for the entering Freshman class in the fall of 1987. The Student Health Service has also been involved in the MIT Medical Department Health Education Task Force, and is working to influence student attitudes through educational efforts in publications, newspaper articles, dorm meetings, computer programs and personal encounters.

7. Surgical Service: The Surgical Services have provided expert consultation and patient care in the Inpatient Unit, minor surgery operating suite and ambulatory surgical clinic. Under Dr. Stephen Healey's leadership, the surgical group has been enormously responsive to the needs of the MIT community and has provided, by example, tertiary surgical care at the hospital level, plus thoughtful continuing care after early transfer of patients to the MIT Inpatient Unit. This has resulted in greater patient satisfaction and economies.

ARNOLD N. WEINBERG, M.D.
Several events marked Fiscal 1987 as a special year at The MIT Press. We celebrated the twenty-fifth anniversary of The MIT Press imprint. We consolidated our entire organization under one roof in newly renovated quarters at 55 Hayward Street in Kendall Square and we also doubled the size of our bookstore on the corner of Main and Carleton Streets by expanding into adjacent space. Despite being in the center of a seemingly permanent construction site, we had a record-breaking year in sales. We published the second edition of the monumental Encyclopedic Dictionary of Mathematics as well as our first bona fide stand-alone software package, Safra and Goldberg: Wisdom Prolog. Textbook sales took a sharp turn upward, particularly with the introduction of a half a dozen important texts including Rumelhart and McClelland: Parallel Distributed Processing; Sterling and Shapiro: The Art of Prolog; Stillings: Introduction to Cognitive Science; Baynes et. al: After Philosophy; Demers: Linguistics Workbook. Our international sales broke the $2 million mark, up about 30 percent over last year, helped both by aggressive promotion abroad, the issue of special paperback editions for foreign textbook markets, and, of course, the declining value of the dollar in Japan and Europe. We also launched a formal program of organizational development using outside process consultants, and we completed our first year of affirmative action internship.

We published 158 titles: 122 original publications, and 36 paperbacks reprinted from our own hardcover backlist. While we published three percent more new books compared with Fiscal 1985, unit sales of new books were up nine percent. We sold 541,000 copies of our books this year compared with 541,000 last year.

MIT AUTHORS

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agha</td>
<td>Computational Complexity and Natural Language</td>
</tr>
<tr>
<td>Barton, Berwick, Ristad</td>
<td>Macroeconomics and Finance: Essays in Honor of Franco Modigliani</td>
</tr>
<tr>
<td>Dornbusch, Fischer, Bossons</td>
<td>NBER Macroeconomics Annual 1986</td>
</tr>
<tr>
<td>Fischer</td>
<td>AI in the 1980s and Beyond</td>
</tr>
<tr>
<td>Grimson And Patil</td>
<td>Computational Limitations for Small Depth Circuits</td>
</tr>
<tr>
<td>Hastad</td>
<td>Assymetries in Time</td>
</tr>
<tr>
<td>Norwich</td>
<td>Theory of Recursive Functions and Effective Computability</td>
</tr>
<tr>
<td>Rogers</td>
<td>Collected Scientific Papers, volume 5</td>
</tr>
<tr>
<td>Samuelson</td>
<td>Cellular Automata Machines</td>
</tr>
<tr>
<td>Toffoli &amp; Margolus</td>
<td></td>
</tr>
</tbody>
</table>

SOME OF OUR BESTSELLERS FROM THIS YEAR'S LIST

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baynes, Bohman, McCarthy</td>
<td>After Philosophy</td>
</tr>
<tr>
<td>Breit &amp; Spencer</td>
<td>Lives of the Laureates</td>
</tr>
<tr>
<td>Crippa</td>
<td>Carlo Scarpa</td>
</tr>
<tr>
<td>Demers</td>
<td>Linguistics Workbook</td>
</tr>
<tr>
<td>Dennis</td>
<td>Court and Garden</td>
</tr>
<tr>
<td>Dornbusch</td>
<td>Dollars, Debts and Deficits</td>
</tr>
<tr>
<td>Gowans</td>
<td>The Comfortable House</td>
</tr>
<tr>
<td>Holland et al</td>
<td>Induction</td>
</tr>
<tr>
<td>Horn</td>
<td>Robot Vision</td>
</tr>
<tr>
<td>Kaufman &amp; Mallory</td>
<td>The Last Extinction</td>
</tr>
<tr>
<td>Martin</td>
<td>Advanced Database Techniques</td>
</tr>
<tr>
<td>Rumelhart &amp; McClelland</td>
<td>Parallel Distributed Processing</td>
</tr>
<tr>
<td>Sterling &amp; Shapiro</td>
<td>The Art of Prolog</td>
</tr>
</tbody>
</table>
Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Akhundov
Baba
Cherniak
Day
Di Sciullo & Williams
Feldman
Fodor
Frisby
Longuet-Higgins
Lyons
Marcuse
Ogilvie
Santayana
Szilard
Ulichney
Upton
Wang

Conceptions of Space and Time
Microprogrammable Parallel Computer
Minimal Rationality
Education for the Industrial World
On the Definition of World
Japanese Financial Markets
Psychosemantics
Fragments of Modernity
Mental Processes
The Disappearance of Introspection
Hegel's Ontology and the Theory of Historicity
Women in Science
Persons and Places, critical edition
Toward a Livable World
Digital Halftoning
Holy Things and Profane
Reflections of Kurt Godel

New hardcover books for trade and general audiences included:

Antebi & Fishlock
Bloktamp et al.
Duboy
Fitchen
Forester
Harris
Kaufman & Mallory
Khan-Magomedov
Langley et al.
Le Corbusier
Lundstrom
Schodek

Biotechnology: Strategies for Life
De Stijl: The Formative Years
Lequeu: An Architectural Enigma
Building Construction before Mechanization
The High-Tech Society
The Arts at Black Mountain College
The Last Extinction
Rodchenko: The Complete Work
Scientific Discovery
The Journey to the East
A Few Good Men from UNIVAC
Landmarks in American Civil Engineering

Books published primarily as texts included:

Baynes et al
Demers & Farmer
Devitt & Sterelny
Jacquemin
Martin
Rowe
Stillings et al.
Sterling & Shapiro

After Philosophy
A Linguistics Workbook
Language and Reality
The New Industrial Organization
The Meaning of Language
Design Thinking
Cognitive Science: An Introduction
The Art of Prolog

Editors in the Acquisition department include: Frank Satlow (Engineering & Computer Science); Laurence Cohen (Sciences, STS, Linguistics & Philosophy); Roger Conover (Architecture and Design Arts); Mark Rakatansky (Architecture and Design Arts); Terry Vaughn (Economics and Management); Robert Bolick (Oxford); Harry & Betty Stanton (Cognitive Science, Bradford Books); Terry Ehling (Computer Science); and Charlotte Richie (Assistant Acquisitions Editor).

BOOK PRODUCTION

Under the direction of Helen Osborne, managing editor, and Dick Woelflein, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Diane Jaroch, upheld the Press tradition of award-winning jacket and book design, garnering honors from the New England Book Show, the Association of American University Presses, the Art Director's Show of Boston, Print Magazine, and The American Institute of Graphic Arts.
### COMPARATIVE OPERATING RESULTS (in thousands)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>1987</th>
<th>Fiscal Year</th>
<th>1986</th>
<th>Fiscal Year</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Net Book Sales</td>
<td>$7,941</td>
<td>$6,939</td>
<td>$5,930</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>3,408</td>
<td>3,034</td>
<td>2,666</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Margin on Sales</td>
<td>4,533</td>
<td>3,905</td>
<td>3,264</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Pub. Income</td>
<td>135</td>
<td>333</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bookstore Net</td>
<td>40</td>
<td>40</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Income</td>
<td>4,708</td>
<td>4,278</td>
<td>3,323</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Expense</td>
<td>4,840</td>
<td>3,966</td>
<td>3,407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Books Division</td>
<td>(132)</td>
<td>16</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Journals Net</td>
<td>(113)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL PRESS</td>
<td>$ (245)</td>
<td>$ 255</td>
<td>$ 17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Press received approximately $40,000 in subventions aiding the publication of four of its titles during the past year. Among the sources of subvention were the National Endowment for the Humanities, the Nederlandso Organisatie voor Wetenschappelijk Onderzoek, and several anonymous donors. These grants helped make possible the production of Blotkamp et al./De Stijl: The Formative Years, Harris/The Arts at Black Mountain College, Santayana/Persons and Places, Critical Edition, and Stoeckle/Encounters between Patients and Doctors. Among the books receiving awards were: John Staudenmaier's Technology's Storytellers (Sigma Nu National Book Award) and William Baumol's Superfairness (first prize for Business, Management, and Economics given by the Association of American Publishers annual given by the Association of American Publishers annual awards program for excellence in professional and scholarly publishing).

Faculty serving on The MIT Press editorial board in 1985-1986 were Professors Harold Abelson, John de Monchaux, Richard Held, John P. Longwell, Daniel Osherson, Merritt Roe Smith, Robert Solow, and Carl Wunsch. Jay Lucker, Constantine B. Simonides, and Frank Urbanowski served as ex-officio members. Professor Ascher Shapiro served as chairman of the editorial board.

The MIT Press management board met twice during the year. Members of the board are Robert M. Solow, Professor in the Department of Economics and Chairman of The MIT Press Editorial Board; Christopher T. Walsh, Head, Department of Chemistry; Arthur L. Singer, Jr., Vice President, Alfred P. Sloan Foundation; Alvin J. Silk, Associate Dean of the Sloan School; Ann F. Friedlaender, Dean, School of Humanities & Social Science; Jeremiah Kaplan, President, Macmillan Publishing Co., Inc.; Norman Pomerance, Vice President, General Books Group, Harper & Row; Jack Schulman; and W. Bradford Wiley, Chairman, John Wiley & Sons, Inc. Professor Shapiro, chairman of the editorial board, and Mr. Urbanowski, Director of the MIT Press, are ex-officio members. Mr. Simonides, Vice President in the Office of the President, is chairman of the management board.

### BOOK PROGRAM

The complexion of our list continues to reflect our intention to devote most of our resources to building depth in our programs in architecture and design arts, computer science and artificial intelligence, cognitive science and linguistics, economics and philosophy, with the balance of our efforts devoted to publication of important works in science, technology, and society and in science and engineering.
BOOK SALES

<table>
<thead>
<tr>
<th>Customer Type</th>
<th>Fiscal Year 1987</th>
<th>Fiscal Year 1986</th>
<th>Fiscal Year 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in thousands)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College Bookstore</td>
<td>$1,531</td>
<td>$1,280</td>
<td>$1,154</td>
</tr>
<tr>
<td>Retail Bookstore</td>
<td>1,685</td>
<td>1,440</td>
<td>1,275</td>
</tr>
<tr>
<td>Wholesale/Jobber</td>
<td>1,475</td>
<td>1,420</td>
<td>1,250</td>
</tr>
<tr>
<td>College/University Library</td>
<td>75</td>
<td>110</td>
<td>129</td>
</tr>
<tr>
<td>Direct Mail</td>
<td>746</td>
<td>520</td>
<td>426</td>
</tr>
<tr>
<td>To Individuals</td>
<td>592</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Totals</td>
<td>6,206</td>
<td>5,340</td>
<td>4,734</td>
</tr>
</tbody>
</table>

Under the direction of Tom McCorkle, sales through regular channels improved significantly. Sales increased from $5,898,659 to $6,840,602, or by about 16.0 percent. Total unit sales also showed an increase from 513,000 to 540,616, or 5.2 percent, another indicator for a healthy publishing program.

INTERNATIONAL SALES AND SUBSIDIARY RIGHTS

International book sales increased by 33 percent in Fiscal 1987, topping the $2 million mark. While sales of the new edition of The Encyclopedic Dictionary of Mathematics (EDM2) contributed significantly to the increase sales were up by 25 percent even after deducting EDM2 sales.

The recent opening of new universities and new university departments expanded the book market in Japan. Our on-the-spot representatives there acted quickly to maximize sales in the larger market and the result was 78 percent sales growth (46 percent without EDM2).

Totally new marketing arrangements in Australia, which for MIT Press had long been a stagnant sales territory, led to a 64 percent jump in sales (61 percent without EDM2).

The drop in the value of the U.S. dollar against UK and Europe currencies (making MIT Press books much less expensive than in the past several years) combined with publication of new MIT Press books especially suited to the European market created expanded sales opportunities. Our London-based sales and marketing staff took advantage of these opportunities and realized a 25 percent gain in sales (EDM2 was not a factor; it was not sold through that office until August 1987).

INTERNATIONAL BOOK SALES FY 1984-1986

<table>
<thead>
<tr>
<th></th>
<th>Fiscal Year 1986</th>
<th>Fiscal Year 1986</th>
<th>Fiscal Year 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australasia</td>
<td>$ 63,800</td>
<td>$ 38,900</td>
<td>$ 32,300</td>
</tr>
<tr>
<td>Canada</td>
<td>308,200</td>
<td>272,900</td>
<td>238,800</td>
</tr>
<tr>
<td>Japan</td>
<td>520,400</td>
<td>292,100</td>
<td>284,900</td>
</tr>
<tr>
<td>Rest of Asia/Other</td>
<td>229,140</td>
<td>197,200</td>
<td>172,100</td>
</tr>
<tr>
<td>Latin America</td>
<td>27,700</td>
<td>21,200</td>
<td>24,500</td>
</tr>
<tr>
<td>UK/Europe</td>
<td>902,200</td>
<td>724,300</td>
<td>656,300</td>
</tr>
<tr>
<td>Totals</td>
<td>2,051,440</td>
<td>1,546,600</td>
<td>1,408,900</td>
</tr>
</tbody>
</table>

In subsidiary rights, 14 titles sold to bookclubs and 35 translation contracts were signed. Total were signed. Total income for subsidiary rights was up 126 percent over FY 1986.

SUBSIDIARY RIGHTS INCOME FY 1984-1986

<table>
<thead>
<tr>
<th></th>
<th>Fiscal Year 1987</th>
<th>Fiscal Year 1986</th>
<th>Fiscal Year 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Translation Rights</td>
<td>$87,449</td>
<td>$36,296</td>
<td>$28,511</td>
</tr>
<tr>
<td>Book Club Rights</td>
<td>71,924</td>
<td>20,152</td>
<td>12,533</td>
</tr>
<tr>
<td>Reprint Rights</td>
<td>14,773</td>
<td>20,555</td>
<td>18,334</td>
</tr>
<tr>
<td>Totals</td>
<td>174,146</td>
<td>77,003</td>
<td>59,378</td>
</tr>
</tbody>
</table>
DIRECT MAIL AND PROMOTION

Under the direction of Brooke Stevens, the promotion department had a rewarding year in all of its communications and selling programs.

Direct mail sales for the year were $746,400, a 42 percent increase over Fiscal Year 1987. The Press mailed out catalogs in computer science, cognitive science, economics, and architecture, a sales catalog (with an all-time record income of $193,000) and brochure packages on The Encyclopedic Dictionary of Mathematics (sales of $50,700), The Comfortable House (sales of $58,600), Biotechnology, and The Complete Works of Rodchenko. For the first time ever, direct mail returns topped $100,000 a month.

Text sales promoted through direct mail and telemarketing reached $1,700,000, a 20 percent increase in dollar sales over last year. Unit sales increased by 9.5 percent.

The exhibit program, which doubled in size in Fiscal Year 1987, has now settled into attendance at around twenty major trade and scholarly meetings where editors meet potential authors and the Press takes orders for books. The program is profitable and provides valuable feedback on our various markets.

Advertisements for The MIT Press publishing programs and books appeared in over 2350 trade and scholarly journals and magazines.

The publicity manager garnered major review in such diverse publications as Scientific American (Forsyth: Buildings for Music); Business Week (Yoshino: The Invisible Link); The New York Times Book Review (Sander: Citizens of the 20th Century; Bloch: The Principle of Hope; Kaufman: The Last Extinction; Rumelhart: Parallel Distributed Processing; Duboy: Lequeu; Santayana: Persons and Places; Khan-Magedov: Rodchenko); and Byte (Sterling: The Art of Prolog). Among the books receiving awards were John Staudenmaier's Technology's Storytellers (Sigma Nu National Book Award) and William Baumol's Superfairness (first prize for Business, Management, and Economic Books given by the Association of American Publishers annual awards program for excellence in professional and scholarly publishing).

JOURNALS

The Journals division had gross sales of $1.8 million, an eight percent increase over last year.

Three new publications were launched in 1987: Assemblage, a journal of architecture and design theory and criticism, edited by Michael Hays, Princeton; The International Journal of Supercomputer Applications, edited by Joanne Martin, IBM; and a second annual series from the National Bureau of Economics Research on Tax Policy edited by Lawrence Summers, Harvard. The Quarterly Journal of Economics, edited by Blanchard, Maskin and Summers was also added to the program.


Assemblage received a $120,000 grant from the J. Paul Getty Trust for start-up funds over a three-year period. October received a $25,000 grant from the Getty Trust for a special issue on Georges Bataille. The Drama Review received an honorable mention from the Association of American Publishers' Professional and Scholarly Publications division for Best Single Issue for a special issue on Polish theatre. In honor of Computer Music Journal's tenth anniversary we produced a compact disc of computer music compositions, distributed in the U.S. by MIT Press and overseas by a West German firm.

Frank Urbanowski
Major effort has been devoted to recruitment of secretarial staff this year. Our turnover rate in the secretarial staff has continued to rise and the pool in the greater Boston area grows smaller each year. Successful recruitment to fill positions is a major concern.

A strategic review of benefits was launched this year with a steering committee composed of senior officers. In view of new laws, changing employee attitudes and perceptions, and the need for increased cost effectiveness, an in-depth look at our benefit package was imperative. As a result of this review, we expect that our benefit package overall will be stronger and more favorably perceived when the review is completed and changes communicated to the community.

Training and development programs continue to be appreciated by participants. More emphasis was placed on providing programs designed for individual departments.

Once again, the staff has worked hard and productively for which I thank them. Overall, it was an exciting year.

There were several staffing changes during the year. Virginia Bishop retired after 29 years of service. Carl Belforti and James McCarthy joined the staff as Personnel Officers. Mr. McCarthy was previously the Administrative Officer in the Center for Technology, Policy, and Industrial Development. Carl Whitaker was hired as supervisor of Benefit Systems and Records.

Those leaving included Ornah Becker, Donna Taylor and Kenneth Chin. Mr. Chin assumed a position in the Research Laboratory of Electronics. Esther Hanig left the Child Care Office and was replaced by Kathy Simons.

JOAN F. RICE

PERSONNEL DEVELOPMENT

During 1986-1987, a total of 5,200 employees participated in Personnel sponsored program presentations offered within laboratories, departments, and centers; and sponsorship for outside educational opportunities through the Tuition Assistance Program.

A wide variety of training and development opportunities were presented at the Institute. Fourteen new or revised programs were added addressing an assortment of job-related and career-related topics. Programs designed specifically for individual departments were presented 16 times. In total, 49 different training programs were offered during the year and most of them were repeated several times.

Many of the presenters in the programs are members of the MIT community who continue to provide their time and expertise to the training effort.

SUSAN WARSHAUER

COMPENSATION

Benefits Administration

During the past year, the Compensation Office has been deeply involved in monitoring benefits legislation enacted by the Commonwealth of Massachusetts and by the U.S. Congress. The Consolidated Omnibus Budget Reconciliation Act (COBRA) and the Tax Reform Act of 1986 were of special interest and concern to the Institute. Last fall and winter the office prepared detailed communication materials and answered numerous inquiries about the extensive and complex impact of these acts on employee benefits, particularly on the Institute's retirement, tax deferred annuity, and health insurance plans.
The Compensation Office continued to devote a significant amount of time and effort to the improvement of its record keeping and processing functions. The past year saw the final development and installation of a major new benefits database as an adjunct to the Personnel system. In addition, the office has developed two sophisticated personal computer databases to handle the complex record keeping required for compliance with COBRA and administration of the Institute's Flexible Reimbursement Account Program (FRAP). During the first six months of calendar year 1987, 365 COBRA notifications were sent and monitored. Of these, 65 individuals have elected to continue their MIT group health insurance coverage through the COBRA continuation period. Two other personal computer databases developed last year to administer the Children's Scholarship Plan and the Tuition Assistance Plan are undergoing conversion to the main Personnel system.

The Compensation Office counselled some 170 retirees on an individual basis this year, in addition to the nearly 270 employees who attended the fall and spring pre-retirement planning seminars. Approximately 125 death and disability claims were processed as well. An additional phone extension was installed specifically for handling retirement, death and disability inquiries.

Effective July 1, 1986, an ad hoc adjustment to retirement income was authorized for those members who retired from employment with MIT prior to July 1, 1985, and were receiving benefits from the Retirement Plan for Employees (RPE).

During the last year, the Compensation Office conducted ten workshop sessions for current employees, including health insurance enrollment workshops and FRAP workshops. We also held 124 orientation sessions for new faculty, academic, sponsored research, administrative staff, and support and service staff members. In addition, the Compensation Office responded to approximately 40,000 telephone calls and to the 3,500 faculty and staff who visited the office.

Wage and Salary Administration

The Compensation Office continued its work to provide fair and equitable salary administration across the Institute through the annual review process, and in the review and analysis of individual salary increases and promotion recommendations submitted by departments throughout the year. The annual review cycle begins with preparation for the Sponsored Research Staff Review early in October, and proceeds through the academic year to encompass the review of Support Staff, Faculty, Academic Staff, and Administrative Staff, concluding with year-end reports to the Executive Committee of the Corporation in early June. Through these annual merit reviews, approximately 8,000 individuals received consideration for salary adjustment this year, based on conditions as they exist in the appropriate marketplace, the Institute's economic outlook, and the relationship of the Institute's salary position to these conditions. Participation in approximately 35 salary surveys during the year, and particularly in the MIT Faculty Salary Survey, the national R & D Survey, and the MIT Administrative and Professional Salary Survey, enables us to assess the Institute's position to these markets, and to make informed recommendations to the Executive Committee for adjustments to the Institute's existing salary structures and pay rates.

Twenty-seven universities participated in MIT's 1986-1987 nationwide Faculty Salary Survey. This survey enabled us to provide an extensive analysis of the competitive marketplace to the School Deans and to other Senior Officers prior to the Faculty salary review in February.

As in the past, MIT participated in two different local surveys to assess the market position of the Support Staff among major Boston area employers. These surveys assess benchmark positions occupied by over half the population of the Support Staff, including Lincoln Laboratory.

Twenty-two universities and nine area employers participated in MIT's Fall 1986 Administrative and Professional Salary Survey. This survey, now in its twelfth year, surveys 40 benchmark positions on the administrative staff for comparison of average salaries, salary ranges, and similarity of organizational structure.

A total of 154 requests for reclassification on the Administrative Staff were received during the year: 76 requests to assess newly created positions; 17 promotional requests for individuals moving from Support Staff and from Exempt; 32 requests to reevaluate existing positions and their salary ranges; and 29 requests for title changes. In reviewing these requests, we have continued to rely on organization charts which display structures of departments as well as entire organizational areas. These charts have become a valuable tool in illustrating for Senior Officers the departments which report to them, and in determining comparable structures in new departments. As new positions are developed, or existing ones redefined, we have begun to build a database of description, based on material submitted by individual departments.
FACULTY AND STAFF INFORMATION SERVICES

Faculty and Staff Information Services has the responsibility for the receiving, processing and physical electronic storage of employment information of faculty and staff. The office is also responsible for privacy of access to these records, the preparation of documents for the annual review cycle, and providing information systems to the Personnel Office and to consumers of personnel information throughout the MIT community.

The office processed approximately 14,000 appointments and changes. This was an increase over last year's activity. There was also an increase in both in-house and outside programming requests. The rise in internal requests was due partly to the addition of the benefits information into the benefits database while the increased external requests were the result of departments becoming more computerized and wishing to add employee information to their systems.

The type of programming requests changed this year as well. Several departments asked to have the output sent to them electronically or converted into spread sheet format. This clearly moves us in a direction that is consistent with the goals of the Institute-wide strategic plan for computational support of business activities.

The office was also involved in the development of the accessible employee database pilot project of the strategic plan. The result of this effort is an employee database with various levels of security. This database was made available to those on the pilot project. The level of access was dependent on the individual's function at the Institute.

CLAIRE PAULDING

LABOR RELATIONS

As of June 30, 1987 the Labor Agreements governing the relationship with the Hotel, Restaurant, Institutional Employees & Bartenders Union Local #26 AFL/CIO for employees in the Food Services and at the Faculty Club terminate for the last time. We wish all the employees governed by these Agreements well with their new employer, the ARA Corporation, who is now responsible for the management of the Food Services and the Faculty Club at the Institute. This Union has represented employees at the Institute since 1936.

The Campus Police Association opened collective bargaining for a new Agreement in May 1986. The negotiations continue as of this date. The issues remain money, management's rights, significant increased cost and a greatly reduced work schedule commonly known as the "4/2". The Federal Mediation Service has attempted to assist the parties to reach a settlement but without success. The membership is currently voting on a revised offer proposed by the Institute.

Grievances and arbitrations have been reduced. There are fifteen contractual issue arbitrations pending and four 2A classification arbitrations awaiting hearing. All these cases are with the Research Dev. & Technical Employees Union. In the past ten years there have been as many as thirty-six arbitrations pending on June 30 of a given fiscal year. During this fiscal year 45 pending grievances and arbitrations were settled by the parties and two (2) issues were heard in arbitration. The unions won one (1) and the Institute was awarded one (1) decision. The award to the Institute was a landmark arbitration which reaffirmed the Institute's right to promote employees based on job performance. Seniority remains a significant factor in promotions, but is governing only when qualifications of two or more individuals are equal.

Currently there are four new Agreements being negotiated with the Campus Police Association, Service Employees International Union Local 254 AFL/CIO (two separate Agreements - Campus and the Lincoln Laboratory) and the Research Development & Technical Employees Union. We look forward to reasonable solutions being reached with these bargaining units early in the new fiscal year.

JAMES J. FANDEL
PERSONNEL SERVICES AND EMPLOYMENT

Personnel Services has the responsibility for the development and interpretation of policies and procedures, and for the coordination of personnel and employment matters.

Seven Personnel Officers, with defined organizational unit responsibilities, have endeavored to continue to contribute to organizational objectives by carrying out personnel activities which seek to provide for an effective workforce. The activities focused on this past year have included improving existing human resource information systems, providing advice and guidance that better recognizes and provides for the diversity of workers, anticipating and providing for the impact of change on the organization, and creating new ways to meet the many challenges of human resource management.

EMPLOYMENT ACTIVITY

Trends in the economy as well as changes in population statistics have had a dramatic effect on the employment activity this year. Increased competition in business and changes in the demographic and the geographic distribution of the population have resulted in spot shortages of skills and talents and in a smaller pool of applicants available for our jobs. We are also experiencing significant change in the diversity of the values and needs of the workforce combined with changing requirements of the work itself. All these factors have made it extremely difficult to maintain a continuous flow of qualified applicants requiring us to pursue more extensive recruiting efforts and a more careful screening process to better control the cost of training and turnover. We have expanded our recruitment efforts taking into consideration the above factors and have experienced some success with our programs. However, we will have to continue to expand our efforts in the future to adapt to the challenges we see before us.

This past year 1418 positions were posted, a 42% increase over the year before. Personnel Officers interviewed 677 applicants referring approximately 75% to departments for consideration. The total applicant pool was 8910 from which 972 were hired. In addition, 261 employees transferred into new positions within the Institute.

SUSAN P. GASKELL

CHILD CARE

The Child Care Office continues to address the child care needs and concerns of MIT-affiliated families through the provision of resource and referral services. During the past year the Child Care Office received approximately 1500 calls relating to child care issues; parent requests included assistance in locating child care, after-school programs, summer camps, vacation child care, swim classes, and other children's programs and specialized services. The Office saw continued interest in its lunchtime discussion series on parent issues as well as in brochures and literature on parenting issues. The office obtained a computer in June in order to facilitate the referral process, report writing and materials production.

In offering support to the network of family day care providers on campus, the Office continued to offer a regular newsletter and provide training sessions and to sponsor an evening ESL class. The Office initiated a weekly story/activity hour during the winter and wrote a successful proposal to establish a library of toys and materials for loan to providers. The Office established a close, effective working relationship with the newly established local family day care licensor, particularly in respect to resolving a regulatory issue in the West Gate low-rise apartment complex.

Special projects this year included five IAP programs, including several designed in collaboration with other departments at MIT for parents with their children, and a successful Children's Picnic for all children, parents and child care providers within the MIT community. Following a decision by the Commencement Committee to review the need for Commencement Child Care and insurance-related issues, the Commencement Day Child Care program was suspended for this year.

Technology Children's Center again completed the program year with full capacity enrollment. A waiting list existed throughout the year and only few openings occurred for new children. TCC serves about 100 children ages 2 years 9 months to five years of age. The Center offers full and half day care and its programs are designed to promote social, emotional and cognitive development. Parents continue to be encouraged to visit and participate on an informal basis.

The close working relationship between TCC and the Child Care Office continues to be felt. The resources offered by the two facilities reassure new and prospective parents in their search for appropriate child care.

LOUISE FLAVIN
Quarter Century Club

The MIT Quarter Century Club membership now totals over 2000, with each member having served the Institute for more than 25 years. At the annual meeting, which was held in March, 110 new members were inducted. The other Club functions are the picnic held in August, attended by approximately 900, and the holiday gathering in December. The staff of the Club provides administrative and logistical support to the Institute’s United Way campaign, which, last year raised 98 percent of its goal or $246,000. The Institute Retirement Dinner is organized and administered by the staff. June ceremonies were held for 169 retiring employees. The office also administers the MIT Activities Committee (MITAC) which organizes recreational and cultural activities for the community. The Club provides service and space to a chapter of the American Association of Retired Persons, Inc. (AARP) which has approximately 250 active members.

An extensive travel program is organized by the manager and reviewed by a committee for the alumni, retirees, and the Institute community. Last year, 35 departures to various destinations worldwide were offered with most of the trips including some educational aspect.

The Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Vice President in the Office of the President. There are four officers and a nine member board of directors with Daniel H. Gould serving as Chairman of the board. Full board meetings are held twice annually. The staff of the Club consists of Ann P. Brazier, manager, and three assistants, M. Frances Daly, Nanci Drago and Diane Tavitian.

JAMES J. FANDEL
Secondary Technical Education Project

The Secondary Technical Education Project (STEP) was created in 1974 in response to Judge Arthur Garrity's request that Boston area colleges and businesses assist Boston Schools during the period of court ordered desegregation.

MIT is responsible, in an advisory capacity, to a newly appointed headmaster of Mario Umana Harbor School of Science and Technology, Dr. Joseph Arangio, Jr. This has been another difficult year for Umana High School in that a city-wide reorganization committee has recommended the closing of all MAGNET SCHOOLS. The school system is now in the process of re-thinking all school pairings with businesses, colleges and cultural institutions. Until this process is completed, Dr. Laval Wilson, Superintendent of the Boston Public Schools has asked MIT to continue in an advisory capacity at Umana, while initiating a new relationship with Boston Latin School. We are now exploring, with the Headmaster, how we could be useful in helping his faculty do a better job retaining minority students and assisting highly motivated students think about careers in science and technology.

Under the direction of the STEP Ad Hoc Committee, Director Alan Dyson now spends 60% of his time working with the faculty of Mario Umana School and 40% of his time as the newly appointed Executive Director of the Cambridge Partnership for Public Education, Inc.

HIGHLIGHTS 1986-1987

Cambridge Public Schools

The STEP Director and Walter Milne served on a steering committee which has now become incorporated into the Cambridge Partnership for Public Education, Inc. This new (October 1987) not-for-profit organization links major businesses, colleges/universities and the public schools in an effort to move information, expertise, and technical assistance between members to improve the educational opportunities for all students in Cambridge. Alan Dyson is on loan from MIT to the 'Partnership' as its first Executive Director. This first year, the 'Partnership' has focused on linking knowledge producers with knowledge users.

Programs

Management Mentors - Linking private sector managers with administrators/supervisors in the public schools.

Fellowships for Teachers/Administrators - Harvard has established a Conant Fellows program and Lesley College has established a program for Cambridge teachers and administrators.

Mini-Grants - In the entrepreneurial spirit, the 'Partnership' has awarded 13 grants for a total of $5250 to encourage teachers to take risk and to think boldly.

Literacy Program - Established a program in an elementary school which linked 'poor' readers to computers, in an effort to change their attitudes about reading.

Marketing the Public Schools - MIT and Harvard are assisting the Cambridge Rindge and Latin School plan a video tape which will be used to market the opportunities for students as they move from elementary schools into the high school.

John Turner, Assistant Provost and Walter Milne, Assistant to the President, serve on the Board of Directors of the Cambridge Partnership for Public Education.

Boston Public Schools

MIT hosted a reception for Umana faculty following Umana's graduations exercises in Kresge Auditorium.

Programs

Faculty, staff, and students served as consultants in the following programs:

Publishing the first Umana School newspaper.

Expanding the on-campus writing/arts program for Umana students.
Tutoring English as a Second Language.

Expanding the opportunities in Electronics and Medical Technology.

Assisting students for participation in the Science Fair.

Writing proposals.

Advising Department Heads.

Updating plan for use of computers.

ALAN DYSON
DOROTHY MAC DOUGALL
This report summarizes the activities and the changes in membership over the past year of the Institute's governing body. The Secretary of the Corporation serves as the Corporation's Recording Officer and as joint signatory with the President in the awarding of the academic degrees of the Institute. MIT's trustees rely upon the Office of the Secretary of the Corporation to provide a range of support for the members and for the Corporation committees.

CORPORATION MEMBERSHIP

At the year's end membership of the Corporation consisted of 72 Active Members (42 Term Members, 22 Life Members, and 8 Ex Officio), and 24 Life Members Emeriti. This grand total of 96 compared with 98 members at the close of the previous year.

Completion of Service

On June 30, 1987, the following seven members completed their designated terms of service: David R. Clare '45; Bernard W. Harleston; David I. Kosowsky '52; Angus N. MacDonald '46; Edward T. Thompson '49; Frank S. Wyle '41; Heidi R. Wyle '82.

Their many contributions to MIT and especially to the work of the Corporation have been deeply appreciated. We look forward to their continuing participation in the life of the Institute through committee service, Campaign activities, and alumni affairs.

In December, 1986, Clifton R. Wharton, Jr., resigned from the MIT Corporation. Dr. Wharton had accepted the position of Chairman and Chief Executive Officer of TIAA-CREF, and, since that is one of the companies that offers tax-deferred annuity programs to members of the MIT faculty and staff, Dr. Wharton wished to avoid any perception of conflict of interest. We were sorry to lose him, but at the same time we understood the considerations that led to his decision. We are grateful for the contributions he made during his term on the Corporation.

Elections

Effective July 1, 1987, eight new members were elected to the Corporation for the terms indicated.

For Five Years Beginning July 1, 1987: E. Rudge Allen '48; John K. Castle '63; Robert B. Horton '71; Walter J. Humann '59; Shirley A. Jackson '68; F. Richard Meyer, III '42. (Dr. Jackson and Mr. Meyer have served previous terms on the Corporation.)

For Five Years Beginning October 1, 1987: Robin M. Wagner '86.

For Two Years Beginning July 1, 1987: Dolores Wharton.

In addition, two members of the Corporation were re-elected to five-year terms, effective July 1, 1987:

Rita A. O'Brien '77; Frank Press.

Two members of the Corporation were elected to Life Membership, effective July 1, 1987: Jerry McAfee '40; Yaichi Ayukawa '52.

Alumni Association President

On June 30, Joseph G. Gavin, Jr., '41 completed his term of service as President of the Alumni Association and was succeeded by Raymond S. Stata '57. We are fortunate each year to have alumni of such competence and dedication willing to take on this very demanding assignment for twelve months.

Transfer to Emeritus Status

Under Section 5.2 of the Bylaws, Robert C. Gunness, having reached the age of 75, transferred to the status of Life Member Emeritus. At the October, 1986, meeting of the Corporation, Dr. Saxon recognized Mr. Gunness's extraordinary record of service as an MIT trustee covering nearly three decades.
Deaths

At the June meeting of the Corporation, Mr. Vetter, on behalf of an ad hoc committee that included Messrs. Kerr, Johnson, and Wiesner, presented memorial resolutions honoring Life Member Clint W. Murchison, Jr., who died on March 30. A loyal alumnus, dedicated trustee, and generous benefactor, Mr. Murchison was associated with the Institute for more than four decades. He was highly regarded by his MIT colleagues and will be greatly missed.

At the March meeting of the Corporation, Mr. Vetter, on behalf of an ad hoc committee that included Dr. Press and former MIT Presidents Stratton, Johnson, and Wiesner, presented memorial resolutions honoring Ida M. Green, Life Member Emerita, and wife of Life Member Emeritus Cecil H. Green. Mrs. Green died on December 26, 1986. On May 1 a memorial service was held at MIT for Mrs. Green in the Ida Green Lounge of the Cecil and Ida Green Building. Corporation members participating in the service included Messrs. Saxon, Gray, Johnson, Press, and Green. Also taking part were Professor Emeritus Robert R. Shrock and the Dean for Undergraduate Education, Margaret L. A. MacVicar. The service was attended by an overflow audience. As trustee and benefactor, Mrs. Green made enormous contributions to MIT. She will always be considered one of the great women in MIT history.

CORPORATION COMMITTEES

Executive Committee

In the past we have not included in this Report an account on the meetings of the Corporation Executive Committee. The Committee is chaired by the President and includes the Chairman and Treasurer ex officio and seven elected members, who this year were Mrs. Emily V. Wade and Messrs. Austen, David, Gavin, McAfee, Mueller, and Vetter. I serve as Secretary, and the Provost is invited to attend all the meetings. The Executive Committee meets regularly each month during the academic year (ten meetings).

The agenda of the Executive Committee include reports of the President, the Chairman, and the Treasurer, and its actions range from receiving Visiting Committee reports, to salary and investment policy, and approval of the budget and of all senior appointments in the Faculty and Administration. The records of its meetings represent the backbone of the formal history of institutional decisions that require the participation and approval of the MIT trustees. At each quarterly meeting of the Corporation, the Secretary submits a report on the actions and deliberations of the Executive Committee. Members of the Corporation accept and discuss this report and are invited to comment and to take any action they deem appropriate on the items reported.

The broad scope and wide-ranging responsibilities of the Executive Committee defy a concise summary of its annual activities. MIT is deeply appreciative of the trustees who give so much of their time and energy to this Committee.

Corporation Development Committee

The activities of this committee during the past year are covered in the report of the Vice President for Resource Development.

Investment Committee

The Investment Committee met three times during the past year. Representatives of the firm of Thorndike, Doran, Paine & Lewis, which serves as investment manager and advisor on general investments, participated with appropriate members of the MIT administration in these meetings. The Committee reviewed the status of the general investments, considered various investment proposals, and provided recommendations for the distribution rate to Pools A and C of the general investments. The general investments are more completely described in the Report of the Treasurer. On June 30, 1987, Carl M. Mueller completed twelve years as Chairman of the Committee but has agreed to continue as a member of the Committee. As of July 1, 1987, Breene M. Kerr, who has been a member of the Committee for the last five years, will succeed Mr. Mueller as Chairman.

Membership Committee

The Membership Committee was chaired by Dr. David S. Saxon, and included this past year Messrs. Gray, Johnson, Kane, Kerr, Leventhal, and Swanson. It held formal meetings in October and December for substantive discussions of membership matters. In the remaining months of the academic year, the members stayed in touch by telephone as nominations were reviewed and information exchanged. The results of this year's deliberations are recorded earlier in this report.
In addition, Dr. Heidi R. Wyle, Chairman, and the other members of the Screening Committee, Dr. Fulbright, Ms. Peck, Ms. Roane, and Mr. Koerner worked diligently with Mrs. Dorothy G. Adler of the Alumni Office, to provide a slate of candidates for the special election by which a recent graduate is nominated to membership in the Corporation. The Corporation Screening Committee met three times during the 1987 process: one open meeting with students in November 1986, a Committee teleconference in January, and an all-day meeting at MIT in February 1987. The five members of the Committee chose a ballot of nine nominees from 110 candidates from the MIT classes of 1985, 1986, and 1987, to elect a Representative From Recent Classes to serve on the Corporation for a five-year term. This year's slate included nine individuals drawn from a group of 110 candidates from the classes of 1985, 86, and 87. Ms. Wagner was the winner of the special election as indicated above.

Auditing Committee

The Auditing Committee of the Corporation met twice in 1986-87, on October 1, 1986, and March 5, 1987. Auditing Committee members were joined by representatives of the independent public accountants, Coopers & Lybrand, together with appropriate members of the administration of the Institute.

At the fall meeting, the Committee discussed the Financial Statement for the year Ended June 30, 1986 while the spring meeting was devoted to setting the scope of the audit for the year ending June 30, 1987 and reviewing the report of internal audit operations.

On June 30, 1987, George P. Gardner completed 13 years of distinguished service as Chairman of this Committee. Harold J. Muckley, who has served for many years on the Committee, succeeds Mr. Gardner as Chairman.

Advisory Committee on Shareholder Responsibility

The Advisory Committee on Shareholder Responsibility (ACSR), under the chairmanship of D. Reid Weedon, Jr., met three times during the past year. Through its recommendations it assisted the Executive Committee on matters concerned with MIT's actions as a socially responsible owner of corporate stocks. Staff work was provided by Walter L. Milne, Assistant to the President and to the Chairman of the Corporation, and Ronald P. Suduiko, Special Assistant to the Chairman.

Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC), led by Chairman Emily V. Wade, met frequently through the summer and fall of 1986. The focus on campus-wide communication about South Africa culminated on February 4, 1987, in a forum on South Africa co-sponsored by CJAC and the Institute Colloquium Committee. Corporation Member David R. Clare gave a keynote address, and a number of other Corporation members attended. At one point in the afternoon the trustees present outnumbered the students who turned out in relatively small numbers. One of the suggestions that came out of the discussions on South Africa was a proposal, still under review, for an exchange program involving teachers from South Africa.

By the end of the spring term, the Committee had identified several topics for consideration at meetings in the coming year.

CORPORATION VISITING COMMITTEES

Twelve Visiting Committees met during the 1986-87 academic year:

<table>
<thead>
<tr>
<th>Department/School</th>
<th>Date</th>
<th>Chairman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political Science</td>
<td>October 7-8</td>
<td>Angus N. MacDonald</td>
</tr>
<tr>
<td>Ocean Engineering</td>
<td>October 20-21</td>
<td>Joseph G. Gavin, Jr.</td>
</tr>
<tr>
<td>Humanities Department</td>
<td>October 29-30</td>
<td>Mary Frances Wagley</td>
</tr>
<tr>
<td>Student Affairs</td>
<td>November 2-4</td>
<td>D. Reid Weedon</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>December 3-4</td>
<td>Frank T. Cary</td>
</tr>
<tr>
<td>and Computer Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Biological Sciences</td>
<td>February 25-26</td>
<td>Herbert H. Dow</td>
</tr>
<tr>
<td>Mathematics</td>
<td>March 17-18</td>
<td>Howard W. Johnson</td>
</tr>
<tr>
<td>Physics</td>
<td>April 7-8</td>
<td>Frank Press</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>April 22-23</td>
<td>Jerry McAfee</td>
</tr>
<tr>
<td>Economics</td>
<td>May 5-6</td>
<td>Ellmore C. Patterson</td>
</tr>
<tr>
<td>Economics</td>
<td>May 19-20</td>
<td>Mitchell W. Spellman</td>
</tr>
<tr>
<td>Sponsored Research</td>
<td>June 16-17</td>
<td>Robert A. Charpie</td>
</tr>
</tbody>
</table>
Chairman Saxon's efforts to encourage committee chairmen to report promptly on their Visiting Committee meetings have been very successful. The Corporation has already heard reports on seven of the twelve committees that met during the 1986-87 academic year, and it is anticipated that the remaining five reports will be given this fall. In addition, six of the committees that met this year have already submitted written reports.

We report with sadness the deaths of three Visiting Committee members: Marvin A. Asnes (Whitaker); Allan V. Cox (Earth Atmospheric and Planetary Sciences); George H. Vineyard (Nuclear). Each of these men will be remembered for his important contributions to the committee on which he served. The Visiting Committees serve a very important function at MIT. The advice and counsel of individual committees can stimulate and influence the activities of those areas they serve. In addition, through the reports of the committee chairmen, the trustees of MIT are kept informed on the Institute's research and teaching programs and the well-being of its students and faculty. This year 470 individuals served on 26 Visiting Committees.

MEETINGS OF THE CORPORATION

The Corporation met, as scheduled, on the first Fridays of October, December, and March, and on Commencement Day, Monday, June 1, 1987.

Orientation Program

On October 2, 1986, the day preceding the Annual Meeting, once again, an orientation program was held for new members of the Corporation. This program, which was started several years ago at the suggestion of Dr. Saxon, includes a luncheon with senior officers, an afternoon program of presentations on the structure of the Corporation and an overview of the university followed by a campus tour and dinner with members of the Executive and Membership Committees.

Annual Meeting

The Annual Meeting on October 3, 1986 was a full-day session with a working lunch. Following the morning annual business meeting, the afternoon program was devoted to presentations and discussions of activities related to the ongoing review and reform of the undergraduate academic program. The comments of Provost John M. Deutch and Margaret L. A. MacVicar, Dean for Undergraduate Education, were well received by the members of the Corporation, who expressed much interest in this subject. There was a lively discussion in which the deans of the schools, who had been invited to attend the afternoon program, also participated.

December Meeting

At the quarterly meeting on December 5, 1986, the members heard a report on recruiting and admissions by Michael C. Behnke, Director of Admissions. Following Mr. Behnke's remarks, the members of the Corporation were shown the slide show which is now being used for recruiting purposes. At the end of the presentation the Corporation members applauded with enthusiasm. There was a spirited question-and-answer period which included discussion of financial aid, applications from foreign students, and ways of predicting academic success.

The dedication of the McNair Building followed that afternoon and will be described elsewhere in this report.

March Meeting

At the quarterly meeting on March 6, 1987, Professor John M. Deutch led a discussion on the future direction of the Department of Humanities. Dean Ann F. Friedlaender, Professor Philip S. Khoury, and Professor Edward F. Crawley made individual statements and then responded to questions. A number of Corporation members participated in the wide-ranging discussion that followed. At the close of the morning session, members of the Corporation were joined by the academic deans and approximately fifty assistant professors for luncheon at the Faculty Club. There was no formal speaking program in order to allow maximum time for Corporation members to talk informally with the young faculty. The idea for this kind of luncheon came from the Provost, and the event was judged a great success by those who participated.

Commencement Meeting

As always, the Corporation held a short breakfast meeting prior to the Commencement exercises, which this year fell on Monday, June 1, 1987. The main business of the meeting was the election of new members, and the results of that election have been noted earlier in this report.
Following the meeting, 29 members of the Corporation marched in the academic procession to Killian Court. Dr. Saxon presided at the graduation exercises, Mr. Olsen gave the Commencement address, and President Gray delivered the charge to the graduates. As President of the Alumni Association, Mr. Gavin was Chief Marshal, and Dr. McAfee served as Marshal of the Corporation. It was the first time for many years that Dr. Stratton and Dr. Killian did not march in the Commencement procession, but both attended the exercises and were greeted by many well-wishers at their seats near the Commencement stage.

BUILDING DEDICATION

At its quarterly meeting on December 5, 1986, the Corporation voted to approve Resolutions naming the building at 70 Vassar in honor of Ronald E. McNair, Ph.D. '77, who had perished in the explosion of the space shuttle Challenger on January 28, 1986. On that same day members of the Corporation and their spouses were guests of the Dedication Committee at a luncheon in the Grier Room of the Fairchild Building also attended by members of the McNair family. Following the luncheon, Chairman Saxon presided at the dedication ceremony in Edgerton Lecture Hall. Taking part in the ceremony were Dr. Shirley A. Jackson; Marine Colonel Charles F. Bolden, Jr.; Professor Michael S. Feld; Ms. Cheryl McNair; and President Gray. Following the speeches, the Chairman and the President escorted Mrs. McNair and her children to Building 37, where they uncovered a plaque inscribed: "Ronald E. McNair Building, Named in Memory of Ronald Erwin McNair, Ph.D., Scientist, Astronaut, Alumnus." The concluding event of the day was a reception in the lobby of the Bush Building open to members of the MIT community.

Members of the McNair family who were present on that day expressed great satisfaction with all the events related to the dedication which, while solemn and moving in appropriate places, overall proved to be a joyous celebration of the remarkable achievements of Dr. McNair's life.

Professor Gene Brown, Dean of the School of Science, served as Chairman of the Ad Hoc Committee on the McNair dedication. We wish to thank, especially, Mary L. Morrissey, Director of the Information Center, and the staff who worked with her for arranging the McNair Building dedication. Miss Morrissey is an expert at handling the many details associated with such a major event, and we appreciate her willingness to take on a task of this magnitude and her competence in bringing it to such a successful conclusion.

CORPORATE LEADERSHIP AWARDS

On April 24, 1987, Chairman David S. Saxon presided at a Corporation luncheon at the Cambridge Marriott Hotel for the conferral of the 1987 MIT Corporate Leadership Awards. These awards were established by the Corporation in 1976 to recognize distinguished corporate leadership by MIT alumni. This year's luncheon marked the sixth occasion on which these awards were presented. There were 64 recipients including three current Corporation members, Messrs. Atwood, Koerner, and Richardson, and two alumni who were subsequently elected to the Corporation at the meeting on June 1, Messrs. Horton and Humann.

Dr. Saxon presided at the luncheon and Dr. Gray joined him for the presentation of inscribed Paul Revere bowls to the recipients. T. R. Wilson was the keynote speaker, and there were a number of other Corporation members present for the luncheon, the lectures, and the other events that were part of the day's celebration.

ACKNOWLEDGMENTS

A special word of appreciation goes to Mrs. Priscilla K. Gray for permitting us to use the President's House for so many Executive Committee and Corporation meetings and other events. Her warm and gracious hospitality means a great deal to the members of the Corporation and to those of us who plan these events year after year.

Walter L. Milne, Assistant to the Chairman and to the President, as always, provided wisdom and counsel based on years of experience with the trustee body. He and his associate Ronald P. Suduiko once again pitched in to help with all major Corporation functions this year.

Nancy R. Spears has decided to resign her post as Assistant to the Secretary for the Visiting Committees in order to pursue a career in writing. This year, once again, Ms. Spears handled the complex arrangements associated with a demanding schedule of meetings with intelligence, skill, and irrepressible humor. For all these qualities, and especially the last, I am grateful to her.

Finally, I wish to acknowledge the excellent work of my close colleague, Elizabeth J. Whittaker, the Assistant Secretary. Miss Whittaker is a perfectionist who manages Corporation meetings, and the affairs of the Secretary's Office with a remarkable sense of service, taste and propriety. The standards she sets for herself and for all of us are the highest. It is both a challenge and a privilege to have her on the team.

CONSTANTINE B. SIMONIDES
Committee on the Visual Arts

The above heading replaces Committee on the Visual Arts (CVA), which for 20 years had identified MIT's internationally recognized program in contemporary art. The change is indicative of the 1986-87 year, one characterized by an ongoing process of evaluation and assessment, both external and internal.

The Committee to Review the Arts at MIT (CRA-MIT) was charged by the Provost to scrutinize all of the Institute's various curricular and non-curricular involvements in the arts. In advance of its recommendations, the position of List Center Director, left vacant with the June 1986 resignation of Kathy Halbreich, could not be filled. Curator Katy Kline agreed to serve as Acting Director for the year. To compensate for the loss of a senior level position, we hired a part-time Curatorial Assistant, Rosanne Rizzi, and engaged consultant Marie Cieri on a part-time basis to evaluate our past performance and possible future initiatives for more effective marketing and audience development, as well as to assist in longer range program planning. She immediately recommended selecting one of the many names (Committee on the Visual Arts, List Visual Arts Center (LVAC), Hayden Gallery, Wiesner Building) by which our activities have been known in recent years; it was decided that henceforth our primary public identification for both location and program would be List Visual Arts Center.

The Committee on the Visual Arts, a presidentially appointed group composed of faculty, administrative staff and students, however, remained an active advisory body, meeting five times during the academic year. Its deliberations focused principally on the definition of its appropriate role vis-a-vis both the wider Institute community and the List Center's professional staff. A subcommittee of Kathryn Lombardi, Leo Marx and Jerry Rothenberg proposed that the CVA's primary energies be directed to facilitating the integration of List Center programs and events more effectively throughout MIT, to enlarge audiences, promote linkages among various disciplines and departments and identify possibilities--of persons or topics--which could enrich the breadth of LVAC educational programs. The energies and insights of members whose terms expired in June 1987 will be sorely missed: David Friedman, Walter Owen, Jerry Rothenberg and particularly Chairman Boris Magasanik, whose steady hands at the helm have guided Committee activities since 1976.

Funding from federal and state arts agencies continued to flourish during FY'87, totaling nearly $140,000. The National Endowment for the Arts awarded the Committee on the Visual Arts monies for the Louise Nevelson and Tony Smith exhibitions. We also continued to be one of the largest recipients of awards from the Massachusetts Council on the Arts and Humanities, with support for "Visionary Apparatus," the residencies of Victor Burgin and Betye Saar, and "Elizabeth Murray: Paintings and Drawings," and for curatorial research. We were also very pleased to receive a generous donation from Mr. and Mrs. A. R. Aralpragasam towards the framing of their gift of 24 Barbara Morgan photographs.

Miscellaneous News Items:

Katy Kline and Assistant Curator Dana Friis-Hansen travelled to the West Coast in March and to the Midwest in May, on travel grants from the Massachusetts Council on the Arts and Humanities, in order to meet with colleagues in museums, galleries and alternative spaces. The extremely instructive conversations exchanged strategies for building support structures, development and expanded educational programming, and have already led to several proposals for fruitful collaborations.

The LVAC received an Award of Excellence from the Art Museum Association of America for the publication "Artists and Architects Collaborate: Designing the Wiesner Building," prepared on the occasion of the inauguration of the building in October, 1985.

To alleviate the disadvantageous Permanent Collection storage conditions at 224 Albany Street, it was decided to transfer the more significant works to the secure and climate controlled Harvard Depository in Southborough.

EXHIBITION PROGRAM

The eleven exhibitions presented in the three galleries of the List Visual Arts Center continued to present the MIT community and other visitors an exciting variety of advanced contemporary art activity in all media. Despite a slightly reduced exhibition schedule, attendance remained steady, and
exhibitions attracted considerable attention from local, regional and national media, including The Boston Globe, Boston Phoenix, WBUR’s Morning Edition, Art New England, Artforum, Art News, and Afterimage. In several instances, adjunct exhibitions in collaboration with other local institutions broadened audience and awareness for our programs.

1986-87 Exhibition Schedule

List and Stratton Student Loan Collection, Hayden and Reference Galleries, September 2 - 19, 1986. The popular annual exhibition and lottery of approximately 300 prints and limited edition artist-designed posters available to students for their living quarters.

Selections from the Permanent Collection, Bakalar Gallery, September 2 - 19, 1987. Recent highlights, currently unsited, culled from the MIT Permanent Collection including portfolios of prints by Josef Albers, Aaron Fink, Lois Lane, James Turrell, William Wegman, and photographs by Edouard Boubat.

Victor Burgin: In Residence, Reference Gallery, September 2 - November 2, 1986. British artist and theorist Victor Burgin applies linguistic and psychoanalytic theory to examine familiar representational art. While in residence Burgin exhibited a recent photographic series "Office at Night" and produced a new work "Danaides/Dames," based on a Sargent mural at the Boston Museum of Fine Arts, which was exhibited at the conclusion of the residency. The List Visual Arts Center co-published (with the Institute of Contemporary Art, London, and the Renaissance Society, Chicago) Between, a 190-page publication surveying 10 years of Burgin’s writing and photographic work. Residency supported in part by the Massachusetts Council on the Arts and Humanities.

Visionary Apparatus: Michael Snow and Juan Geuer, Hayden Gallery, October 10 - December 21, 1986. Machines and devices which examine and extend perception of the natural and technological world were the focus of this exhibition featuring two Canadian artists. It was accompanied by a 52-page illustrated catalogue and supported in part by the Massachusetts Council on the Arts and Humanities.


"Things are Seldom What they Seem," or Local Sculptors/Found Materials, Reference Gallery, November 15 - December 28, 1986. This year's "Local Visions," the annual exhibition which highlights emerging artists in the region, presented inventive work in found and assembled objects by Abram Ross Faber, Brewster Luttrell, and Pia Massie. Accompanied by a 12-page illustrated brochure.


Out of Eastern Europe: Private Photography, Reference Gallery, January 17 - April 12, 1987. The first US exhibition to present photography created outside the governmental artists unions by artists in Czechoslovakia, East Germany, Hungary, and Poland, this exhibition was drawn from the collection of Guest Curator John Jacob. An adjunct exhibition of the Polish artist Anna Bohdziewicz was organized with the Photographic Resource Center, Boston. Accompanied by a 56-page illustrated catalogue. The exhibition will travel to New York, San Francisco, Portland (ME), Philadelphia, and several other sites during a two-year tour.

Tony Smith: The Shape of Space, Bakalar Gallery, January 17 - April 5, 1987. This exhibition celebrated MIT’s monumental minimalist work by Tony Smith, For Marjorie with a presentation of its model and two other major works in bronze. Accompanied by an eight-page illustrated brochure. Supported in part by the National Endowment for the Arts.

Betye Saar: MojoTech, Bakalar Gallery, April 24 - June 28, 1987. Los Angeles assemblage and environmental artist Betye Saar was in residence at MIT for a month to create several new works which investigated the possibilities for magic within modern technology. In addition, a small site-specific work was created and installed at the Museum of the National Center for Afro-American Artists in Roxbury. Supported in part by the Massachusetts Council on the Arts and Humanities.
EDUCATIONAL PROGRAMS

A wide range of educational activities and exhibition-related events were presented at the List Visual Arts Center, open free to the MIT community and the general public.

Informational Texts

All exhibitions were accompanied by an introductory wall text, written by a member of the curatorial staff, which presented the concepts, context and significance of the exhibition. In addition, many of the exhibitions had individual didactic labels for each work, to offer the uninitiated visitor an opportunity to develop a broader understanding and deeper appreciation for advanced contemporary art.

Talks, Tours, and Lectures

Gallery talks at the List Visual Arts Center and tours of the MIT Collection were arranged for a number of groups during the year, including MIT groups such as a freshman seminar and visiting alumni, local school and community groups, and visitors from other organizations including the Whitney Museum of American Art and the Museum of Modern Art, New York.

Each exhibition was accompanied by lectures and special events. Artist in Residence Victor Burgin organized a five-part lecture series examining attitudes towards the hieroglyph as a universal symbolic language. Michael Snow and Juan Geuer participated in a mini-residency which included a Michael Snow film series, a conversation between the artists, and a panel discussion on the topic "Creativity in Art and Science." An informal conversation between the exhibiting artists was hosted for "Things are Seldom What They Seem." Krzysztof Wodiczko presented a major public lecture about his work. Guest Curator John Jacob led a walk-through gallery tour of "Out of Eastern Europe: Private Photography." In conjunction with this exhibition, the LVAC and Boston Film/Video Foundation co-sponsored a four-part Eastern European Film Festival. Artist in Residence Betye Saar discussed her work in a major public lecture, and hosted weekly "Open Studios" in the gallery during the creation of her new works. Finally, Elizabeth Murray spoke about her work during a walk-through gallery talk.

Artists in Residence

The LVAC Artist in Residence program continued to offer invited artists a forum for research and development of new works, drawing upon the intellectual, physical, and technological resources of MIT. The presence and processes of the artists, rather than their product, were emphasized; the community was encouraged to interact with these distinguished visitors during the various public events scheduled during their month-long residency.

ACQUSITIONS

The following works were acquired through either gift or purchase during the 1986-1987 academic year:

Permanent Collection

Robert Cumming, twenty-four Ektachrome photographs, 1986. Twenty were commissioned through funds from the Massachusetts Council on the Arts and Humanities/New Works Program, four were a gift from the artist.


John McNamara, LIQUID SKY, 1985, oil on canvas. Gift of Drs. Salvatore and Zella Luria.

Flora Natapoff, MOVING AROUND, 1983, oil on canvas. Purchased with funds from the Committee on the Visual Arts and Women's Studies Program.


Barbara Morgan, twenty-four black and white photographs, various dates. Gift of Mr. and Mrs. A. R. Arulpragasam.
Lee Friedlander, twenty black and white photographs, 1986. Commissioned through funds from the Massachusetts Council on the Arts and Humanities/New Works Program.


Jan Groover, twenty photographs in various tones, 1986. Commissioned through funds from the Massachusetts Council on the Arts and Humanities/New Works Program.

List Student Loan Collection


April Gornik, UNTITLED, 1985, etching, ed. 16/70. Gift of the Albert and Vera List Collection.

Jon R. Friedman, UNTITLED, 1986, screenprint, AP VI/IX. Gift of the Albert and Vera List Collection.


Ronald A. Kurtz Student Loan Collection


EXTENDED LOANS TO THE COLLECTION

Tony Smith, FOR J.C., 1969, welded bronze. Lent by Mr. and Mrs. Lee V. Eastman.

Terry Winters, VESSEL, 1985, oil on linen. Lent from a private collection, New York

(See also previous annual reports.)
LOANS FROM THE PERMANENT COLLECTION TO OTHER INSTITUTIONS


Joyce Kozloff, THREE FACADES, 1973 and MITLA, 1974, to the Boston University Art Gallery, Boston, for the exhibition Joyce Kozloff: Visionary Ornament, February - April 1986 and subsequent tour to University of New Mexico, Albuquerque, NM; College of Wooster, OH; Hunter Museum of Art, Chattanooga, TN; and Moore College of Art, Philadelphia, PA.

Elizabeth Murray, LAST NIGHT, 1982, to the Dallas Museum of Art, TX for the exhibition Elizabeth Murray: Paintings and Drawings, February - April 1987 and subsequent tour to the Museum of Fine Arts, Boston, MA; The Museum of Contemporary Art, Los Angeles, CA; Des Moines Art Center, IA; Walker Art Center, Minneapolis, MN; and The Whitney Museum of American Art, New York, NY. (This exhibition was co-organized by the MIT Committee on the Visual Arts and the Dallas Museum of Art. While in Boston/Cambridge the paintings from the exhibition were displayed at MIT's List Visual Arts Center and the drawings at the Museum of Fine Arts.)

Beverly Pepper, TRINITY (formerly DUNES I), 1971, to the Albright-Knox Art Gallery, Buffalo, NY for the exhibition Beverly Pepper: Sculpture in Place, September - November 1986 and subsequent tour to the San Francisco Museum of Modern Art, CA; Columbus Museum of Art, OH; Brooklyn Museum of Art, NY; and the Center for Fine Arts, Miami, FL.

CONSERVATION TO THE PERMANENT COLLECTION

Restorative work was performed on Alexander Calder's THE BIG SAIL (La Grande Voile) and Louise Nevelson's TRANSPARENT HORIZON.

Commonwealth Print Conservation, Boston, treated a drawing, RED SYMBOLS, by Georges Mathieu.

Several works on paper were framed or re-framed by Old Cambridge Co., Cambridge.

KATY KLINE
BORIS MAGASANICK
In this, its sixteenth year, the Council looked both backward and forward as it celebrated its first fifteen years, participated in the Institute's comprehensive review and assessment of its arts programs, and embarked on new ventures.

Annual Meeting

The Fifteenth Annual Meeting of the Council took place on October 16 and 17, its theme being the celebration of the Council's Fifteenth Anniversary. On the evening of October 16, Council members attended a piano recital in Senior House, a film screening in the Bartos Theater, and exhibits in the List Visual Arts Center and Compton Gallery.

On October 17, Institute Professor Emeritus Philip Morrison addressed Council members regarding the relationship between art and science. The 1986 McDermott Award was presented to Richard Leacock, Professor of Film, and the 1986 Kepes Prize was presented to Chris Janney, a fellow in the Center for Advanced Visual Studies, each of whom presented a sampling of his work.

Chairman Jerome Wiesner, President Paul Gray and Provost John Deutch addressed the Council at its lunch and business meeting, held at the Sonesta Hotel, compliments of former Council member Roger Sonnabend '46. The day ended with a reception, held at the MIT Museum amidst the Bauhaus exhibit, honoring the Council, Professor Leacock, Mr. Janney, and Institute Professor Emeritus Gyorgy Kepes (on the occasion of his 80th birthday).


Review of the Arts at MIT

In September, Provost John Deutch created an Ad Hoc Committee to Review the Arts at MIT. Chaired by Professor of Economics Paul Joskow, the Committee was charged to review and assess all of the creative arts activities at MIT and to make recommendations regarding their role, organization, and support.

In order that the Council assess its own strengths and future directions, Chairman Jerome Wiesner convened an Ad Hoc Committee of the Council's Executive Committee. That Committee made several proposals to the full Executive Committee, which, in turn, met with Professor Joskow. Subsequently, the Review Committee met with Council members at a Special Mid-Year Meeting held in March. Many ideas and suggestions were exchanged. At this writing, the Review Committee has not yet issued its report to the Provost.

Visiting Artists Program

Completion of the Villers Experimental Media Facility--specifically designed for the development and creative use of new media--made possible the realization of two visiting artist projects. The month of March was devoted to the residency of Antenna Theater of Sausalito, California, whose members worked in collaboration with MIT's Film/Video Section to produce the world premiere of Radio Interference, a high-technology, avant-garde commentary about the effect of technology on human communication. That project was generously supported by grants from the Massachusetts Council on the Arts and Humanities, the National Endowment for the Arts, the Council for the Arts at MIT, American Inroads, the San Francisco Foundation, the CFS Foundation, and the Media Arts and Sciences Program of MIT's School of Architecture and Planning. Radio Interference will have a New York premiere in the fall of 1988 and will then tour nationally.

In May, The Wooster Group, one of America's foremost experimental theater companies, premiered Frank Dell's St. Antony, a paraphrase of Gustave Flaubert's epic work La Tentation de Saint Antoine, directed by Elizabeth LeCompte in collaboration with Peter Sellars. That project was funded in part by the New Works Program of the Massachusetts Council on the Arts and Humanities.

Earlier in the year, the Council sponsored a lecture-demonstration and master class given by Council member and world-renowned choreographer and pioneer of modern dance, Alwin Nikolais.
Grants Program

This year, the Grants Committee, chaired by Bradford M. Endicott '49, received and reviewed 76 proposals from students, student groups, faculty, and staff, requesting a total of $157,117. Of these, 59 projects (78 percent of those submitted) were awarded $73,960 (47 percent of the amount requested). In addition, Council staff made one Officers' Grant for $150.00. A detailed report from the Grants Committee is available.

The Grants Committee this year observed a noticeable increase in projects involving media technology. Ten such proposals were received requesting $29,566. Eight awards totaling $15,535 were made.

Continuing the policy established last year, the Grants Committee convened an extra, year-end meeting to assess its award guidelines and criteria and the overall success of the program. At that meeting, the Committee resolved to explore the possibility of inviting various arts faculty to participate as advisors to its deliberations in order to insure that the Grants Program provides the support most needed by artists in the MIT community.

Publications

Four issues of the Council's calendar/newsletter, The Arts at MIT, were produced and distributed to a mailing list of 8,500 alumni, friends, faculty, staff, student groups, and other individuals.

The Arts Hotline, a weekly telephone announcement of all arts events taking place at MIT was maintained for its third year.

Endowed Prizes and Awards

Walter Rosenblith, Council member and Institute Professor Emeritus, served as the Chairman of the Student Art Awards Selection Committee. The Laya and Jerome B. Wiesner Student Art Awards were presented to Philip S. Hsu '87 (Course V) for his contributions to the MIT Symphony Orchestra, and to Patricia A. Zeitler '88 (Course VI) for her contributions to the Dramashop. The Louis Sudler Prize in the Arts was awarded to graduating senior Andrew Borthwick-Leslie who has participated in MIT's drama activities as an actor, director, and playwright.

The Committee noted a marked increase over past years in both the number and quality of nominations for these awards.

Independent Activities Period

At the suggestion of Council member Gregory Smith '30, the Council sponsored, during IAP, a very successful series of four arts field trips called "Art: A User's Guide." Thirty-five students attended a concert of the Boston Chamber Music Society, a tour of the exhibits in the List Visual Arts Center, a performance of the Bejart Ballet of the Twentieth Century, and a production of The New Repertory Theater, accompanied, respectively, by Marcus Thompson, Professor of Music, Dana Friis-Hansen, Assistant Curator, Beth Soll, Director of the Dance Workshop, and Larry Lane, Acting Director of the Drama Program.

Boston Museum of Fine Arts University Membership Program

For the seventh year, the Council funded MIT's participation in the MFA's University Membership Program which allows all MIT students to attend the Museum at no charge as frequently as they wish. This year's participation was made possible by special contributions from Harold E. Edgerton '27, Bradford M. Endicott '49, and Bernard G. Palitz '47.

Programmatic and Technical Assistance

Council staff have continued to provide advice, ideas, research, and administrative support regarding the development of arts projects or organizations to MIT students, faculty, and staff. This year, Program Officer Mark Palmgren and Grants Committee Chairman Bradford Endicott '49 assisted Ed McCluney, the new Director of the Student Art Association, to obtain the funds necessary to purchase a new kiln. Mark Palmgren is also assisting a task group of the MIT Working Group on Support Staff Issues to develop a Support Staff Art Exhibition.

Development Activities

Most of the Council's funds for both its operating expenses and Grants Program continued to come from Council members and other donors. This year, 63 members made contributions averaging $3,420 each, an amount seven percent higher than last year. Forty-one other donors contributed an average of $575 each.
MIT contributed $38,000 to the Council's budget in exchange for support provided by Council staff to the Ad Hoc Committee to Review the Arts at MIT.

Building on the Council's experience last year in initiating new fund raising vehicles, Associate Director Richard MacMillan worked with a committee of Council members chaired by DeeDee Pharr to plan and stage an opening-night gala for Council members during the run of Radio Interference.

Gifts continued to be made this year to the Roy Lamson Memorial Fund for Music at MIT. The first awards will be made by the Grants Committee next year.

Gifts of Works of Art

Council members have regularly contributed works of art to the MIT Permanent Collection and to the Student Loan Collections. This year, Vera G. List contributed prints by Donald Sultan to the Permanent Collection. To the List Student Loan Program, she gave a woodcut by Rosalyn Richards, a color photograph by Cindy Sherman, and prints by Susan Crile, William Conlon, Jon R. Friedman, April Gornik, Judith Murray, Irving Petlin, Susan Rothenberg, Edward Stasack, and William Zimmerman.

Ronald A. Kurtz '54 made a second gift of fifty black and white photographs by Berenice Abbott to the Ronald A. Kurtz Student Loan Collection.

Alan May '57 continued to support the Alan M. May Fund for the acquisition, framing, matting, and glazing of pictures for the Student Loan Collections.

Membership

At the end of the year, Council membership stands at 89. All of the 17 members whose terms expired this year were asked to renew their commitments.

The Council's Executive Committee established a new Membership Committee, the function of which will be to recommend potential new members for both the Council and for particular committees. President Emeritus and new Council member Howard Johnson agreed to serve as the Committee's chairman.

Personnel

Mark Palmgren joined the staff in July as Senior Staff Assistant, and, following the resignation of Alison Salisbury in January, was promoted to Program Officer. Susan Downing was hired as the new Senior Staff Assistant in February.

HELVI McCLELLAND
Fiscal 1987 is the fourth consecutive year that we have had a modest surplus from financial operations. We are also projecting a small surplus for fiscal 1988 if conditions remain favorable.

By Fiscal 1989, MIT will have an operating budget in excess of $1 billion. Twenty-five years ago, this figure was $110 million (and included the Charles Stark Draper Laboratory -- then called the Instrumentation Laboratory -- which became a separate entity in 1973). Ten years ago the operating budget was $277 million -- less than one-third of the projected budget in 1989.

For over 125 years, MIT has successfully faced the financial challenge of managing growth. In the past quarter century MIT has grown in size and complexity, primarily as the result of externally funded sponsored research programs. This complexity and growth has stretched the resources of the Institute. Among those major universities with which MIT compares, our endowment is the smallest in relation to operating expenses -- in part because we have had fewer decades to build our endowment. While our endowment has grown significantly over the years through the generous gifts and bequests of alumni and other friends, it has not always been possible to preserve all of the unrestricted portion of these gifts as endowment to provide the income for the benefit of future generations of MIT students and faculty.

Our rapid growth in operations certainly heralds the significant achievements of MIT, but it also has created significant financial concerns that must be resolved if MIT is to continue the extraordinary quality of its instructional and research programs. Among these financial concerns are the following:

- spending most unrestricted gifts, grants and bequests for current operations rather than adding them to the endowment to generate future income;
- the need to increase our academic facilities through the purchase, modification, or construction of buildings suitable for academic programs, and having to use current operating revenues to pay for these purchases;
- reliance on sponsored research for over two-thirds of operating revenues; and
- the relatively small portion of discretionary funds in the operating budget.

As with most not-for-profit institutions, MIT aggregates the expenses of its programs (e.g., those for instruction and unsponsored research, direct research expenses, etc.) each year. These expenses are then met by the operating revenue and funds received for operations of that year. These revenues and funds include tuition, research revenues, investment income and restricted gifts. Over the past 25 years these operating revenues and funds have not been sufficient to cover all operating expenses; therefore, other sources of unrestricted funds must be found to meet current expenses. At MIT we commonly refer to this situation as the “additional need for unrestricted revenues and funds.”

This “additional need” is usually met by using all or a portion of the unrestricted gifts we have received rather than adding them to the endowment. When we have more available unrestricted gifts than the “additional need,” we have a “surplus” position and some of these gifts can be added to “endowment.” If there are insufficient unrestricted gifts, then we must draw from “endowment” the amount necessary to meet expenses; this places us in a “deficit” position that year.

During the past decade, we have had to draw on funds other than unrestricted gifts in only two years: In Fiscal Year 1982 in order to meet a significant increase in the need for unrestricted funds for undergraduate student financial aid, and in Fiscal Year 1983 in order to fund a planned program of renovations and upgrading of existing academic and research facilities.

In eight of the last ten years we have had a surplus (a greater amount of unrestricted gifts, grants, and bequests than the additional need). However, even in those years, to the extent we used any unrestricted gifts to meet operating expenses or spent them for capital purchases, we do not have those dollars available for the endowment for future program development.

A major challenge facing MIT is to be able to retain all unrestricted gifts, grants and bequests in “endowment” upon which income can be generated rather than using them to meet the expenses of current operations or for purchases of academic plant.

To continue leadership in our academic efforts we simply need new financial resources. These resources must come from gifts to endowment leading to increased investment income. We cannot look to growth in research efforts or income from rising tuition as realistic options. A major increase in our endowment is
necessary to assure the future income to maintain educational leadership in a rapidly changing technologi-
cal society. This need forms the basis for The Campaign for the Future, an intensive five-year fundraising
drive primarily to increase endowment.

The reports that follow highlight the activities in the five major areas of financial operations. There
were no major organizational changes this year. As a result of earlier recommendations from an evaluation
of the financial area planning process, a Task Group on Career Development met throughout the year to look
at and recommend career development processes within the financial area. The report of the Committee is
presently being reviewed for implementation later this year. The efforts of the members on this Committee
are very much appreciated.

The reports of each department highlight the major activity that has occurred during the year. Brief
reports, however, cannot describe the care and efforts of individuals in the financial area who make these
reports -- and the activities described -- possible. My sincere thanks for the contributions of these men
and women in guiding and documenting the many financial events that have occurred during the year.

Affirmative Action

We have continued our efforts in affirmative action -- to assure that women and underrepresented minorities
have full opportunity for employment, promotion and assignment to rewarding and career-oriented jobs. As
of June 30, 1987, the total of women administrative staff is 70 (38%), while underrepresented minorities
are 16 (9%) of the administrative staff of 185.

Including support and service staff, the percentage of underrepresented minorities is 46 (12%) in a total
staff of 386.

Increasing the numbers of women and minorities in career positions is a major goal of each area in the
financial operations area. We have incorporated the "serious search" procedures formerly performed by the
Academic Council into financial area Department Head review. All appointments to the administrative staff
require pre-search and post-search documentation reviewed by the five senior Department Heads with final
approval, on their advice and consent, by the Vice President.

Attention to affirmative action and making it a priority of the financial area has had good results in the
hiring and promotion of women and underrepresented minorities. We must, however, continue this effort as a
major priority. A few highlights of the past year.

Comptroller's Office

Comptroller's Accounting Office, Lincoln Laboratory Fiscal Office, Audit Division, and Property Office

- The number of women administrative staff members is 32 (36%), out of a total
  administrative staff of 90.
- The total of underrepresented minorities is 16 (8%) of the total staff of 194.
- An underrepresented minority male was appointed to the position of Analyst Programmer
  III.
- An underrepresented minority woman in the Comptroller's Accounting Office was promoted
to Analyst Programmer III from Applications Programmer I.
- Three women in the Comptroller's Accounting Office were promoted from Support Staff to
  Staff Accountants on the administrative staff.
- In the Comptroller's Accounting Office, the following promotions of women occurred; one
to Senior Staff Accountant, two to Assistant Accounting Officer, and one to Accounting
  Officer.
- A woman in the Audit Division was promoted to Audit Manager from Auditor I.
- A woman was hired on the Audit Division Staff as an Assistant Auditor.
Office of the Director of Finance

- The number of women administrative staff members is 6 (50%), out of a total administrative staff of 12.
- The total of underrepresented minorities is 2 (15%) of the total staff of 13.
- A woman was promoted to Senior Budget Officer, the second highest position in the Budget Office.

Office of Purchasing and Stores

- The number of women administrative staff members is 3 (14%), out of a total administrative staff of 22.
- The total of underrepresented minorities is 12 (15%) of the total staff of 78.
- The first minority staff member in the Purchasing and Stores department was appointed in March 1986.
- The department has retained the black Cambridge teen summer student on a part-time basis for the remainder of fiscal 1988.

Office of Registration and Student Financial Services

- The number of women administrative staff members is 20 (54%), out of a total administrative staff of 37.
- The total of underrepresented minorities is 13 (20%) of the total staff of 65.
- In the Registrar's Office, a minority woman was promoted from support staff to administrative staff and the number of underrepresented minorities increased from three to four.
- In the Student Financial Aid Office, a minority woman was promoted from Assistant to Associate Director and the number of underrepresented minorities increased from three to four.
- In the Bursar's Office the number of underrepresented minorities held steady at five and a minority woman was promoted from Assistant to the Bursar to Assistant Bursar.

Office of Sponsored Programs

- The percentage of women administrative staff members is 8 (40%), out of a total administrative staff of 20.
- The total of underrepresented minorities is 1 (3%) of the total staff of 32.
- The Office of Sponsored Programs initiated a summer minority internship this year by employing a Black business student during her summer vacation months.

JAMES J. CULLITON
THE COMPTROLLER'S ACCOUNTING OFFICE — CAMBRIDGE

Payroll

Work continued on the conversion of the Staff Payroll System to the single base Payroll System. This effort was interrupted to comply with and implement an Internal Revenue Service requirement to effect Form W-2 reporting via magnetic tape. The new W-2 system was built to combine campus and Lincoln Laboratory reporting and to include, where appropriate, the reporting of taxable Children's Scholarship payments. Following completion of that project, work resumed on the Staff Payroll conversion toward a July implementation of the disbursement function and a fall implementation of the distribution/accounting function.

Benefits Accounting

This year we updated beneficiary elections as required by the spousal consent provisions of the Retirement Equity Act of 1984. A new annual statement was produced for the Retirement Plan for Staff Members which displayed beneficiary information, method of payment of death benefits and the member’s investment election for allocation of future MIT contributions. The December 1986 annuity payments for retirees of the Retirement Plan for Employees included the increases associated with the past service benefit increase which was applied to active members in July 1985. The Tax Reform Act of 1986 dramatically changed the taxability of partial distributions and the recovery rules of member after-tax contributions — in a retroactive manner. The same Act also invoked prospective changes in maximum deferral amounts, stricter tests in meeting non-discrimination requirements and changes to vesting schedules.

THE LINCOLN LABORATORY FISCAL OFFICE

The Lincoln Fiscal Office continued the development of automated procedures and control systems as well as improving the operational programs and has embarked upon the preparation of an automated purchasing system for the laboratory.

THE PROPERTY OFFICE

The Property Office is responsible for the accounting and asset management of more than 120,000 items of equipment which are both MIT-owned as well as sponsor-owned. During the year, approximately 12,400 newly acquired items of movable equipment were identified and tagged, 100,000 purchase orders reviewed, 148 final inventories and 274 financial reports submitted to various government agencies. $150,000 (original acquisition cost) of excess government equipment was acquired. 540 items of equipment with an acquisition value of $185,141 were transferred between MIT departments as part of a reutilization program, and unneeded equipment sold for $213,787 providing funds for replacement equipment. The Property Office maintains an inventory of equipment available for reutilization or sale which is displayed at the MIT Equipment Exchange.

The equipment and property data base system which supports the activity described above as well as providing the data analysis and support for the indirect cost recovery from sponsors for the use of equipment on a depreciation basis was the subject of an intensive review during the year which resulted in a decision to proceed with the design and implementation of a system with upgraded computation and accounting analysis capability.

The Society for Property Administrators (SPA), which is administered by the Property Office, conducted a three-day Property Management Conference in San Francisco, California, in December, 1986. More than 140 attendees from the United States and Canada were present at the conference. A newsletter was also published and distributed to the nearly 300 Society members.
In August 1986 the Audit Division was reorganized and two senior Audit Manager positions were created and filled by existing staff members. This reorganization from our prior "flat" structure has several objectives including the development of a clear career path for our staff by increasing the responsibility of our more senior members. Another objective is to allow the Director more time and flexibility in developing approaches and identifying areas which could benefit from Audit Division involvement.

An Electronic Data Processing Audit Specialist was added to our staff in February 1987 as part of the Institute's Strategic Plan for Administrative Data Processing. We have already increased our coverage in the data processing area and we expect in the new fiscal year to increase our traditional audit coverage in the areas of review of policy and procedure implementation, internal control review, and asset safeguards.

A financial/audit survey was circulated by the Audit Division to all identifiable operating units of the Institute (183 units) to emphasize the importance of the integrity of our accounting data and the Institute's fiduciary responsibility to donors and sponsors. The survey included, in addition to questions on the unit's method of monitoring receipts and expenditures of all funds, material to assist the operating units in fulfilling their fiduciary obligations and invited questions on financial policy and specific procedures and transactions. The questions received from the survey were used as the basis for discussion in several school and departmental meetings with Administrative Officers and their assistants and a panel from central financial administration. Similar presentations are available to all members of the MIT community and can be arranged by calling the Audit Division.

In September the MIT Audit Division, along with Boston University's Audit Division, hosted the Thirtieth Annual Conference of the Association of College and University Auditors which was attended by more than 400 individuals representing over 200 colleges and universities.

**Personnel Changes**

The following staff changes occurred within the Comptroller's Office during the past year:

<table>
<thead>
<tr>
<th>Appointments</th>
<th>Promotional Appointments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guillermo E. Alvarez-Vega</td>
<td>Deena M. Anundson</td>
</tr>
<tr>
<td>Analyst Programmer III</td>
<td>Staff Accountant</td>
</tr>
<tr>
<td>Glenn H. Myers</td>
<td>Thomas F. Conroy</td>
</tr>
<tr>
<td>Analyst Programmer II</td>
<td>Staff Accountant</td>
</tr>
<tr>
<td>Lisa J. Walker</td>
<td>Susan S. Wu</td>
</tr>
<tr>
<td>Analyst Programmer I</td>
<td>Staff Accountant</td>
</tr>
<tr>
<td>Julia A. Werbinski</td>
<td>Elizabeth A. Duggan</td>
</tr>
<tr>
<td>Auditor</td>
<td>Staff Accountant</td>
</tr>
<tr>
<td>Chester T. Seymour</td>
<td>Ellen M. Sico</td>
</tr>
<tr>
<td>Auditor</td>
<td>Senior Staff Accountant</td>
</tr>
<tr>
<td>Robert F. Matson</td>
<td></td>
</tr>
<tr>
<td>Senior Analyst Programmer</td>
<td></td>
</tr>
<tr>
<td>Dina Kazis</td>
<td></td>
</tr>
<tr>
<td>Auditor</td>
<td></td>
</tr>
<tr>
<td>James Mahoney</td>
<td></td>
</tr>
</tbody>
</table>
Promotions

Demetri A. Karageorge
Assistant Accounting Officer

Paul J. Arsenault
Accounting Officer

Mary Ann Donofrio
Accounting Officer

Laurence J. Connelly, Jr.
Assistant to the Comptroller

Alan E. Harrington
Accounting Officer

Robert M. Slauzis
Accounting Officer

Stephen J. Gorman
Accounting Officer for Investments

David Mark Sprague
Analyst Programmer II

Sheriefa Siers
Analyst Programmer III

Pamela W. Weldon
Audit Manager

Charles A. Shaw
Audit Manager

Anastasia J. Janus
Senior Staff Accountant

Debra E. Cobb
Assistant Accounting Officer

Ann M. Langton
Assistant Accounting Officer

Paul J. Honiker
Comptroller's Personnel Administrator

Philip M. McMahon
Assistant Comptroller

Retirements

Ruth E. Walsh
21 years' service

Richard A. May
27 years' service

Robert R. Ragusa
36 years' service

PHILIP J. KEOHAN
Total operating expenses for the year reached $882.5 million — up 11.4 percent from the previous year. Total operating revenues and funds used were $879.4 million — an increase of 11.2 percent over 1984-85. In comparison, inflation, as measured by the consumer price index for all urban workers, grew by 3.7 percent.

To fund the difference between operating expenses and revenues the Institute used $3.1 million of the $4.3 million of unrestricted gifts, grants, and bequests it received. However, within operating expenses there is a $2.9 million non-mandatory appropriation designated for funding of future academic plant. When this is considered, less than $200,000 of unrestricted gifts were used to fund ongoing operating expenses.

The surplus from operations after the application of unrestricted gifts, grants, and bequests was $1.2 million. This represents the fourth surplus in six years and the eighth in the last decade.

The only cautionary note for the year is found in the growth rate of the modified total direct cost base for campus research. This base grew by 3.0% during fiscal 1987. When the campus research base grows at a rate less than that of instruction and unsponsored research (11 percent), then the likelihood of future financial pressure on unrestricted resources increases.

In fiscal year 1987 the Budget Office continued to enhance its "local area computer network" that links together individual computer work stations to the office's database. This state-of-the-art system has improved our ability to perform special budgeting work. A decision was made in mid year to stop further work on the mainframe budget system which has been in some state of development for a number of years. As an alternative to that system, a consultant was used to develop requirements for a system that better matches current hardware options with management reporting needs. It is expected that the new system, based on a database management software and a microcomputer, will be completed with the next fiscal year.

Personnel

During the year Deborah Fairchild was promoted to the position of Senior Budget Officer and Gregory R. Arsenault was promoted to the position of Analyst Programmer II. Patricia Bullock joined the Budget Office as a Budget Officer II at the beginning of the fiscal year.

JOHN A. CURRIE
Major projects/accomplishments this year include:

1) Development of a fully automated, integrated, on-line Purchasing, Accounts Payable, and Receiving System, which commenced during the previous year as a joint project of the Department of Purchasing and Stores and the Comptroller's Accounting Office, continued throughout the year. The System will allow all purchasing offices, research laboratory purchasing agencies and fiscal offices, Accounts Payable, and other administrative offices to create, print, store, display, and process entire purchase order, invoice, and receiving information on-line. The System is expected to be ready for implementation in October of the coming year.

2) Reporting responsibility of the Graphic Arts Purchasing Office was transferred from the Director of Graphic Arts to the Director of Purchasing and Stores. The Office, which is physically located at Graphic Arts, is organizationally an extension of the General Purchasing Office, and provides procurement services for the substantial printing, forms and related requirements of Graphic Arts, the MIT Press, and all on-campus departments, centers, and laboratories.

General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Of a total 91,000 purchase orders issued by all on-campus purchasing agencies, the General Purchasing Office processed and issued 61,000 or 67 percent of the total.

Since a primary responsibility of this Office is the purchase of required goods and services at lowest practicable prices, major emphasis continued to be placed on negotiating discount agreements and other favorable pricing arrangements with suppliers.

Office of Laboratory Supplies

Combined sales of office and laboratory items, furniture and furnishings, and personal computers increased 8.5 percent over the previous year. While sales of office and laboratory items and furniture and furnishings increased slightly, sales of personal computers increased 50 percent.

The established Office of Laboratory Supplies' systems for purchasing, receiving, storage, inventory control, delivery, coordination with the Property Office, and internal billing continued to be utilized to support the Microcomputer Center's personal computer resale programs.

Minority and Woman-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of over $10.0 million to minority and woman-owned business concerns. For the first time, the Institute exceeded the $5.0 million level in awards to minority business concerns, and the $4.0 million level in awards to woman-owned business concerns. Over $5.4 million was awarded to 295 minority businesses and over $4.7 million was awarded to 648 woman-owned businesses. Accomplishments this year represent a 43 percent increase over the previous year.

Subcontracting Plans Under Federal Contracts

It is the policy of the United States (Public Law 95-507) that each contract proposal to a Federal agency which exceeds $500,000 be accompanied by a Subcontracting Plan which specifically identifies the efforts that will be undertaken to assure award of a fair proportion of subcontracting and purchasing dollars to small business concerns and small minority business concerns. The Subcontracting Plan includes both dollar and percentage goals which are negotiated with the sponsor and ultimately made a material part of the resultant contract.

As a service to departments, laboratories, and centers, members of this Department coordinate with the Office of Sponsored Programs and principal investigators, prepare Subcontracting Plans for submission, negotiate changes when necessary, and report accomplishments to Federal sponsors, principal investigators, and personnel who have been designated Subcontracting Plan Administrators by principal investigators. The number of active Subcontracting Plans under Institute Federal contracts has grown from 25 in 1980 to a high of 70 this year, necessitating the submission of over 200 separate reports of accomplishments annually to Federal sponsors. Additionally, in order to provide guidance and assistance to principal investigators and subcontracting plan administrators, over 300 internal progress reports are issued annually.

BARRY ROWE
Significant change occurred in this Office as the year ended. After 36 years of service and leadership in the Registrar's Office, Warren D. Wells '48 retired at the close of the year. Mr. Wells joined the Office in 1951 as Assistant Registrar and became Registrar in 1964. Under his leadership, increasingly sophisticated and effective electronic data processing techniques were introduced and implemented in the Registrar's operations. The development more than twenty years ago of the General Academic Simulation Program (GASP) system represented, for students and faculty alike, a tremendous step forward in flexibility and avoidance of conflicts in scheduling and represented a creative use of the talent so evident in our students in the development of a large-scale piece of software. For this, as well as for many other notable achievements, the Institute is much in his debt.

A nationwide search for Mr. Wells' replacement was initiated at the beginning of the year, and a Search Committee was established to advise me in the process. The Committee, comprised of Professor Alar Toomre, Margaret Richardson, Assistant Dean for Curriculum Support, and Robert Weatherall, Director of Career Services and Preprofessional Advising, unanimously recommended the promotion of Dr. David S. Wiley, '61, who was then Associate Dean and Section Head of the Undergraduate Academic Support Office in the Office of the Dean for Student Affairs. Dr. Wiley received the S.B. and S.M. in Physics from MIT, and, in 1966, his Ph.D. from Princeton University. He returned to MIT in 1972 and served as Senior Associate, Analytical Studies and Planning Group, and Executive Officer for the Committee on Educational Policy, Faculty Policy Committee, and the Committee on the Undergraduate Program. I am delighted with the prospect of working closely with Dr. Wiley, as I have from time to time in the past with great admiration.

The Office's affirmative action efforts throughout the year have succeeded in increasing the percentages of underrepresented minorities, and in several significant promotions. These were:

In the Registrar's Office, Varian Woolfork was promoted from support staff to administrative staff as supervisor of the Registration Section, and the number of underrepresented minorities increased from three to four.

Yvonne Gittens was promoted from Assistant Director to Associate Director of Student Financial Aid, and the number of underrepresented minorities in that office increased from three to four.

In the Bursar's Office the number of underrepresented minorities held steady at five, and Carlene Chisom-Freeman was promoted from Assistant to the Bursar to Assistant Bursar.

Taken together, the percentage of underrepresented minorities increased from 17% to 20%.

Following are the separate reports of the Bursar, the Registrar, and the Director of Student Financial Aid.

JACK H. FRAILEY, Director

BURSAR'S OFFICE

Overview

Major achievements in the Bursar's Office were in three areas:

- loan system-- We have completed the conversion to the Wachovia Services, Inc. data processing and billing system, which will enable us to provide more efficient and effective service to our borrowers. Changing servicing needs of alumni and changing reporting needs of the federal government, as well as MIT's need for access to improved financial analysis tools, were the major reasons for the conversion. We had approximately 12,000 borrower accounts (many with several loans) to convert to the
There were concerted efforts to improve all written information (instructions which accompany student account statements, letters to new students, etc.) to provide students with clear, concise, and accurate information. We enhanced communication with MIT departments through cross training and input to policy development.

**Student Services**

Student tuition, fees, and other charges totaling $131,520,954 were billed, an increase of 6.5% from last year. Servicing the 10,057 student accounts required 207,832 transactions to the student accounts receivable system. Income from late payment fees was $88,479 and income from finance charges was $176,619.

**Student Loans**

Student loans receivable totalled $39.1 million at fiscal year end. These notes are funded by $12,943,598 of MIT loan funds established by friends and alumni of the Institute, $19,836,575 of federal funds in support of the National Direct Student Loan (NDSL) program, $121,905 of federal funds borrowed to support a portion of our contribution to the NDSL program, $3,116,907 borrowed from the Student Loan Marketing Association (SLMA), and $3,100,000 borrowed from local banks.

After ten years of growth, MIT's Parent Loan Program (PLP), established in 1977 to assist parents of students receiving little or no financial aid, experienced a decline this year. This decline is attributable to the change in the tax laws last fall, whereby the tax deductibility of the interest paid on these loans is being phased out. More parents are now turning to home equity loans to finance their children's education. We expect the PLP to continue to be an important source of funding to many of our families; approximately thirty-five families from the Class of 1991 plan to use our PLP, down from the previous years' average of one hundred. There are now 543 active PLP accounts with an outstanding balance of $3,364,290. A total of $2,567,897 was disbursed during the year and principal collected was $3,144,834. This program is fully funded by a loan from SLMA.

**Student Loan Collection**

The delinquency rate as a percent of active loans increased slightly this year from 22.9% to 23.5%. Loan receivables increased 2.2% to $39,118,985 and loans in active status rose 4.1% to $23,568,374.

MIT's default rate on National Direct Student Loans (NDSL) was 1.1% in 1986 (as compared to 1.2% in 1985); our default rate on Federal Insured Student Loans (GSL/FISL) was 2.0% in 1986 (as compared to 2.3% in 1985). The 1986 national default rate for NDSL loans was 7.7%; the corresponding 1986 national default rate for GSL/FISL loans was not available from the Department of Education when this document went to press, but the 1985 figure was 9.1%.

**Information Systems**

The conversion from our in-house loan billing and data processing system to Wachovia's was completed in May. The loan servicing staff works with this new system via direct online access and a wide range of accounting and management reports.
The acquisition of a network of six Apple Macintosh computers has allowed the
distribution of many word processing tasks throughout the office. The staff has been
able to produce more of their own reports and correspondence, freeing up support staff
for other tasks. A laserprinter has allowed us to produce "camera ready" forms and
brochures, saving on typesetting costs.

Staff Notes

Peter H. Brown joined our staff as Associate Bursar/Information Systems in July. He came
to us from MIT's Dean for Student Affairs Office, where he was Assistant Dean for
Student Affairs.

Carlene Chisom-Freeman, Assistant to the Bursar/Loan Collection, was promoted to
Assistant Bursar/Loan Programs Administration in March.

Maureen C. De Courcey resigned her position as Assistant Bursar/Loan Programs
Administration in January.

Margaret L. Nelson joined our staff as Assistant to the Bursar/Loan Collection in
October. She came to us from Massachusetts Higher Education Assistance Corporation,
where she was a claims representative and loan collector.

Eleanor B. Smalley, Assistant to the Bursar/Student Accounts, retired in September.

Kenneth R. Weekees joined our staff as Assistant to the Bursar/Loan Collection in June.
He came to us from Middlesex Community College, where he was Coordinator of Student
Loans/Employment.

SHIRLEY M. PICARDI, Bursar

REGISTRAR'S OFFICE

Enrollment

In 1986-87 student enrollment was 9,756, compared with 9,787 in 1985-86. This total was
comprised of 4,443 undergraduates (compared with 4,541 the previous year), and 5,313
graduate students (compared with 5,246 the previous year). The decline in undergraduates
resulted from a decision by the Institute to decrease the freshman class size below
1,000 in order to address housing concerns. The International student population was
1,896, representing 7 percent of the undergraduate and 30 percent of the graduate
population. These students were citizens of 97 countries.

In 1986-87, there were 2,340 women students (1,295 undergraduate and 1,045 graduate) at
the Institute, compared with 2,218 (1,176 undergraduate and 1,042 graduate) in 1985-86.
In September 1986, 378 first-year women entered MIT, representing 38 percent of the
freshman class.

In 1986-87, there were 1,344 minority students (1,124 undergraduate and 220 graduate) at
the Institute, compared with 1,241 (1,047 undergraduate and 194 graduate) in 1985-86.
Minority students included 300 Blacks (non-Hispanic), 21 Native Americans, 265
Hispanics, and 758 Asian Americans. The first-year class entering in September 1986
included 302 minority students representing 30 percent of the class. Due to changes in
Federal guidelines, beginning 1986-87 students with permanent residence status were
included with U.S. citizens, affecting the counts of both International and Minority
students.

Degrees Awarded

Degrees awarded by the Institute in 1986-87 included 1,159 bachelor's degrees, 1,150
master's degrees, 42 engineer's degrees, 459 doctoral degrees -- a total of 2,810.

Staff Notes

Warren Wells retired as Registrar after 36 years of service in the Registrar's Office,
23 years as Registrar. David Wiley assumed the position of Registrar as of July 1, 1987.
John Blake, Technical Supervisor, transferred to the Alumni Association in February.
Noelle Gove, Supervisor of the records section, retired after 19 years of service.
Tabular Presentation

Most of the above 1986-87 figures are taken from the several tables that follow. These tables, together with others dealing primarily with historical comparison and demographic data, comprise the annual Registrar's Report, separately published and available upon request.

WARREN D. WELLS, Registrar

STUDENT FINANCIAL AID OFFICE

The Washington Watch

The level of activity in the office generated by action by Congress and the Executive Branch probably reached a new peak in 1986-87. Beginning in late summer, the Student Financial Aid Office (SFAO) was obliged successively to re-vamp the application process for Guaranteed Student Loans, implement new data-verification requirements and procedures (only to abandon them in the winter in favor of improved quality control guidelines offered volunteer schools ), understand and act on the Tax Act of 1986, respond to proposed regulations in several program areas, and begin to implement the ill-conceived Immigration and Naturalization Service's employee identification rules. And the Aid profession stands on the verge of a new day in need analysis anti-philosophy, as we wait to be engulfed next year by the "Congressional Methodology" -- representing the legislative branch's successful foray into the financial aid profession's collective judgement and insight of decades.

Refreshment of the Scholarship Endowment

These federally-imposed diversions from our simply-stated mission to deliver financial aid dollars to students coincided with the informal launching of the Campaign For MIT -- a magnum opus that (we fondly hope) will itself have a lasting impact on the aid office. Already the level of development activity has overtaken the aid office in its slipstream, and we have had the privilege of assisting the fund-raising effort by participating in a significant increase in the number of proposals to prospects and reports to donors.

The Need for Financial Aid

The aggregate undergraduate need for assistance grew again, as it does annually. Having identified and diagnosed the three-year reduction in the number of needy students, in FYs 1984, 85 and 86, we were better able to predict FY 1987's number and closed just a little under the target figure for the year. The number, 2360, is 100 less than last year. The average need for help (after parental resources were tapped to a reasonable extent) was $11,650 -- very close (again) to the tuition rate for the year. In the aggregate, the financial aid program required $15,104,000 from needy students' family resources, and provided $27,494,000 in aid dollars. Thus the aid program accounted for 65% of needy students' total costs.

Scholarships and Grants

The year saw the first noticeable drop in grants from federal programs. Changes in eligibility criteria for Pell Grants, and the last-minute cutbacks in the size of ROTC scholarships combined to reduce the federal grants total by 10% -- $300,000. This was more than offset by a healthy increase in income from MIT's own scholarship endowment -- this in turn the happy combination of a strong rate of return on the funds, the addition of several new endowed funds, and the need for a smaller allocation than last year to the International Student Loan Fund reserve. On the negative side, scholarship awards made directly to needy students by outside sponsors remained at last year's level. Overall, the level of awards from designated grant and scholarship resources stood just over ten million dollars and 9% higher than last year. These resources once again fell far short of the need, and the program was augmented by $6,121,000, from unrestricted income, a figure that represents about 11.5% of undergraduate tuition income.
The following table displays the sources of grants and scholarships received by needy students in the last three years:

<table>
<thead>
<tr>
<th>Scholarships and Grants* (awarded to undergraduates with need)</th>
<th>1984-85</th>
<th>1985-86</th>
<th>1986-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pell Grants</td>
<td>$755,000</td>
<td>$825,000</td>
<td>$630,000</td>
</tr>
<tr>
<td>SEO Grants</td>
<td>1,294,000</td>
<td>1,329,000</td>
<td>1,304,000</td>
</tr>
<tr>
<td>ROTC Scholarships</td>
<td>928,000</td>
<td>840,000</td>
<td>767,000</td>
</tr>
<tr>
<td>Scholarship Endowment$</td>
<td>3,553,000</td>
<td>3,540,000</td>
<td>4,813,000</td>
</tr>
<tr>
<td>Current Gifts</td>
<td>739,000</td>
<td>800,000</td>
<td>763,000</td>
</tr>
<tr>
<td>Direct Grants</td>
<td>1,644,000</td>
<td>1,819,000</td>
<td>1,811,000</td>
</tr>
<tr>
<td>Unrestricted Funds$</td>
<td>5,550,000</td>
<td>5,680,000</td>
<td>6,121,000</td>
</tr>
<tr>
<td>Total Grants Awarded</td>
<td>$14,463,000</td>
<td>$14,833,000</td>
<td>$16,209,000</td>
</tr>
</tbody>
</table>

$ Net of Draft to Int'l Student Loan Fund.
% Including Special Program Grants.

As if to give resounding approval to our predictions of the last two years, Congress last year increased the annual limits on individual Guaranteed Student Loans. At the same time, SHARE, a new private parent-loan program, got off to a fine start to demonstrate its acceptance and viability. These developments underscore our optimism that educational loan capital is in abundant supply, and if properly complemented with a vigorous program of grants and scholarships (to keep accumulated debt within reasonable limits), will assure access to MIT for every admitted student with need.

During the spring award season, the Office began in earnest its new role as signposts for parents -- we assimilated from the Bursar the responsibility for citing sources of loan assistance to parents, and advising and directing them toward best choices.

Use of the National Direct Loan Fund by undergraduates continued to grow, as additional federal monies were added during the year to the Institute's substantial revolving fund. The fund was sufficient to provide a maximum of $1,600 this year to each eligible undergraduate; this fact, together with continuing availability of Guaranteed Student Loans at students' banks, kept the demand for the Technology Loan Fund down.
The following table details loan use by undergraduate and graduate students:

<table>
<thead>
<tr>
<th>Loans</th>
<th>(received by needy and non-needy students)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>1984-85</th>
<th>1985-86</th>
<th>1986-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Awarded to Undergraduates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology Loan Fund</td>
<td>$738,000</td>
<td>$823,000</td>
<td>$766,000</td>
</tr>
<tr>
<td>National Direct Loans</td>
<td>2,347,000</td>
<td>2,452,000</td>
<td>2,844,000</td>
</tr>
<tr>
<td>Guaranteed Student Loans</td>
<td>5,719,000</td>
<td>5,629,000</td>
<td>4,834,000</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$8,804,000</td>
<td>$8,904,000</td>
<td>$8,444,000</td>
</tr>
<tr>
<td>B. Awarded to Graduate Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology Loan Fund</td>
<td>$1,420,000</td>
<td>$1,396,000</td>
<td>$1,198,000</td>
</tr>
<tr>
<td>Guaranteed Student Loans</td>
<td>3,390,000</td>
<td>3,395,000</td>
<td>3,350,000</td>
</tr>
<tr>
<td>by Commercial Lenders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guaranteed Student Loans</td>
<td>202,000</td>
<td>120,000</td>
<td>56,000</td>
</tr>
<tr>
<td>by MIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$5,012,000</td>
<td>$4,911,000</td>
<td>$4,604,000</td>
</tr>
</tbody>
</table>

Work Programs

The job market remained strong in the past year, and the average starting rate for off-campus jobs was again well above the Federal minimum wage. The on-campus minimum wage stayed at $5.50. The number of students working on campus again showed no change.

The College Work-Study Program allocation decreased slightly from the 1985-1986 level and was used entirely to subsidize the on-campus student employment program. Approximately two-thirds of the total 1986-1987 allocation was used to subsidize undergraduate work, and one-third to subsidize graduate student teaching assistantships.

The Student Employment Office developed a new computer system during the year to handle college work-study funds. The system makes assignments to the work-study accounts and automatically updates classifications in the payroll files. The system's database is easily accessible, and it reports people who are no longer or never were students, students who are in danger of exceeding their earnings limit, and data on the classifications assigned.

Staff Notes

It was a busy year in the area of personnel changes, too. Dorothy Bowe retired in December, after 32 years of distinguished service at MIT. Her departure was followed by the promotion of Yvonne Gittens to Associate Director, and the promotion of Donna Kendall from our support staff complement to serve as Assistant to the Director. Late in the summer, Lucy Miller culminated nine years of innovative and energetic service in Student Employment and Donor Relations to take a new position in the Resource Development area. She has been replaced by Roger Watkins (BA Boston State, MS Tufts U.), who came to us in January from the Boston Technical Center to become Assistant Director for Donor Relations.

*All of the numbers reported in this section reflect awards from the academic year perspective, and so will not agree exactly with fiscal-year-based records reported by the Comptroller or the Treasurer.

LEONARD V. GALLAGHER, Director
## Classification of Students by School, Course, and Year, 1986-87

<table>
<thead>
<tr>
<th>COURSE NAME</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>G</th>
<th>Non Res.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCHOOL OF ARCHITECTURE AND PLANNING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture, IV</td>
<td>20</td>
<td>28</td>
<td>36</td>
<td>272 (1)</td>
<td>7</td>
<td>363 (1) IV</td>
</tr>
<tr>
<td>Architecture, IV-A</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5 IV-B</td>
</tr>
<tr>
<td>Urban Studies and Planning, XI</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>162 (14)</td>
<td>32</td>
<td>197 (14) XI</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>22</td>
<td>30</td>
<td>40</td>
<td>434 (15)</td>
<td>39</td>
<td>565 (15) Total</td>
</tr>
<tr>
<td><strong>SCHOOL OF ENGINEERING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics and Astronautics, XVI</td>
<td>136</td>
<td>87</td>
<td>82</td>
<td>218 (13)</td>
<td>1</td>
<td>524 (13) XVI</td>
</tr>
<tr>
<td>Aeronautics and Astronautics, XVI-B (Cooperative)</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2 XVI-B</td>
</tr>
<tr>
<td>Aeronautics and Astronautics, XVI-C (Internship)</td>
<td>-</td>
<td>12</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>27 XVI-C</td>
</tr>
<tr>
<td>Chemical Engineering, X</td>
<td>39</td>
<td>45</td>
<td>68</td>
<td>235 (2)</td>
<td>-</td>
<td>387 (2) X</td>
</tr>
<tr>
<td>Chemical Engineering, X-C</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>6 X-C</td>
<td></td>
</tr>
<tr>
<td>Civil Engineering, I</td>
<td>13</td>
<td>27</td>
<td>25</td>
<td>273 (7)</td>
<td>3</td>
<td>341 (7) I</td>
</tr>
<tr>
<td>Civil Engineering, I-A</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1 I-A</td>
</tr>
<tr>
<td>Civil Engineering, I-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>7 I-W</td>
</tr>
<tr>
<td>Electrical and Computer Science, VI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program 1-Electrical Science and Engineering</td>
<td>234</td>
<td>162</td>
<td>222</td>
<td>643 (85)</td>
<td>1</td>
<td>1,500 (85) VI</td>
</tr>
<tr>
<td>Program 3-Computer Science and Engineering</td>
<td>95</td>
<td>68</td>
<td>85</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Electrical and Computer Science, VI-A (Cooperative)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program 1-Electrical Science and Engineering</td>
<td>-</td>
<td>70</td>
<td>53</td>
<td>92</td>
<td>-</td>
<td>276 VI-A</td>
</tr>
<tr>
<td>Program 3-Computer Science and Engineering</td>
<td>-</td>
<td>25</td>
<td>36</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Electrical Engineering and Computer Science, VI-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1 VI-W</td>
</tr>
<tr>
<td>Materials Science and Engineering, III</td>
<td>42</td>
<td>10</td>
<td>19</td>
<td>274 (14)</td>
<td>3</td>
<td>348 (14) III</td>
</tr>
<tr>
<td>Materials Science and Engineering, III-A</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2 III-A</td>
</tr>
<tr>
<td>Materials Science and Engineering, III-B (Cooperative)</td>
<td>3</td>
<td>42</td>
<td>26</td>
<td>-</td>
<td>-</td>
<td>71 III-B</td>
</tr>
<tr>
<td>Mechanical Engineering, II</td>
<td>144</td>
<td>109</td>
<td>112</td>
<td>497 (41)</td>
<td>2</td>
<td>864 (41) II</td>
</tr>
<tr>
<td>Mechanical Engineering, II-A</td>
<td>12</td>
<td>11</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>37 II-A</td>
</tr>
<tr>
<td>Mechanical Engineering, II-B (Internship)</td>
<td>-</td>
<td>28</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>48 II-B</td>
</tr>
<tr>
<td>Mechanical Engineering, II-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2 II-W</td>
</tr>
<tr>
<td>Nuclear Engineering, XII</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>149 (1 )</td>
<td>1</td>
<td>169 (1 ) XI</td>
</tr>
<tr>
<td>Nuclear Engineering, XII-A (Internship)</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1 XII-A</td>
</tr>
<tr>
<td>Ocean Engineering, XIII</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>84 (5)</td>
<td>-</td>
<td>96 (5) XIII</td>
</tr>
<tr>
<td>Ocean Engineering, XIII-C (Internship)</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>16 XIII-C</td>
</tr>
<tr>
<td>Ocean Engineering, XIII-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>-</td>
<td>16 XIII-W</td>
</tr>
<tr>
<td>Naval Construction and Engineering, XIII-A</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>61</td>
<td>-</td>
<td>61 XIII-A</td>
</tr>
<tr>
<td>Ocean Systems Management, XIII-B</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>49 (49)</td>
<td>-</td>
<td>49 (49) XIII-B</td>
</tr>
<tr>
<td>Center for Advanced Engineering Study, EN</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>EN</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>735</td>
<td>695</td>
<td>795</td>
<td>2,610 (217)</td>
<td>11</td>
<td>4,846 (217) Total</td>
</tr>
</tbody>
</table>
### SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

<table>
<thead>
<tr>
<th>Program</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>107</th>
<th>24</th>
<th>185</th>
<th>XIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics, XIV</td>
<td>2</td>
<td>12 (1)</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>29 (1)</td>
<td>XIX</td>
</tr>
<tr>
<td>Humanities, XIV</td>
<td>-</td>
<td>4</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>XIX-E</td>
</tr>
<tr>
<td>Humanities and Engineering, XIX-E</td>
<td>-</td>
<td>6</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td>21</td>
<td>XIX-S</td>
</tr>
<tr>
<td>Linguistics and Philosophy, XIV</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>62</td>
<td>5</td>
<td>75</td>
<td>XIXIV</td>
</tr>
<tr>
<td>Political Science, XVII</td>
<td>3</td>
<td>9</td>
<td>12</td>
<td>126 (13)</td>
<td>47</td>
<td>197 (13)</td>
<td>XVII</td>
</tr>
</tbody>
</table>

**Total**

|                | 29 | 52 (1) | 69 | 295 (13) | 76 | 521 (14) | **Total** |

### SLOAN SCHOOL OF MANAGEMENT

<table>
<thead>
<tr>
<th>Program</th>
<th>19</th>
<th>39</th>
<th>42</th>
<th>444 (16)</th>
<th>6</th>
<th>550 (16)</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management, XV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Management Fellow, XV-A</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-61 (6)</td>
<td>-</td>
<td>-61 (6)</td>
<td>XV-A</td>
</tr>
<tr>
<td>Management-Operations Research, XV-B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-18</td>
<td>-</td>
<td>-18</td>
<td>XV-B</td>
</tr>
<tr>
<td>Management-PH.D., XV-P</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-81</td>
<td>-</td>
<td>-81</td>
<td>XV-P</td>
</tr>
</tbody>
</table>

**Total**

|                | 19 | 39 | 42 | 604 (22) | 6  | 710 (22) | **Total** |

### SCHOOL OF SCIENCE

<table>
<thead>
<tr>
<th>Program</th>
<th>54</th>
<th>73</th>
<th>61</th>
<th>152 (3)</th>
<th>-</th>
<th>340 (3)</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Biological Sciences, XX</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>101 (2)</td>
<td>-</td>
<td>103 (2)</td>
<td>XX</td>
</tr>
<tr>
<td>Biology, VII</td>
<td>10</td>
<td>6</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>20</td>
<td>VII-A</td>
</tr>
<tr>
<td>Biology, VII-A</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-32</td>
<td>VII-B</td>
</tr>
<tr>
<td>Biology, VII-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>20</td>
<td>VII-W</td>
</tr>
<tr>
<td>Chemistry, V</td>
<td>24</td>
<td>24</td>
<td>42</td>
<td>223</td>
<td>-</td>
<td>313</td>
<td>V</td>
</tr>
<tr>
<td>Earth, Atmospheric, and Planetary Sciences, XII</td>
<td>5</td>
<td>16</td>
<td>12</td>
<td>117 (2)</td>
<td>2</td>
<td>152 (2)</td>
<td>XII</td>
</tr>
<tr>
<td>Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>77</td>
<td>-</td>
<td>77</td>
<td>XII-W</td>
</tr>
<tr>
<td>Mathematics, XVIII</td>
<td>36</td>
<td>36</td>
<td>49</td>
<td>123 (3)</td>
<td>-</td>
<td>249 (3)</td>
<td>XVIII</td>
</tr>
<tr>
<td>Mathematics with Computer Science, XVIII-C</td>
<td>22</td>
<td>14</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>-50</td>
<td>XVIII-C</td>
</tr>
<tr>
<td>Physics, VIII</td>
<td>60</td>
<td>63</td>
<td>70</td>
<td>291 (8)</td>
<td>2</td>
<td>486 (8)</td>
<td>VIII</td>
</tr>
<tr>
<td>Physics, VIII-A</td>
<td>20</td>
<td>18</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>42</td>
<td>VIII-A</td>
</tr>
</tbody>
</table>

**Total**

|                | 247 | 261 | 262 | 1104 (18) | 11 | 1885 (18) | **Total** |

### WHITAKER COLLEGE of Health Sciences, Technology, and Management

<table>
<thead>
<tr>
<th>Program</th>
<th>6</th>
<th>12</th>
<th>12</th>
<th>44</th>
<th>-</th>
<th>74</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain and Cognitive Sciences, IX</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Health Policy and Management, HPM</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Harvard-MIT Division of Health Sciences and Technology, HST**

<table>
<thead>
<tr>
<th>Program</th>
<th>71 (48)</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>71 (48)</th>
<th>HST</th>
</tr>
</thead>
</table>

**Undesignated**

<table>
<thead>
<tr>
<th>Program</th>
<th>55 (1)</th>
<th>30 (30)</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>85 (31)</th>
<th>Undesignated</th>
</tr>
</thead>
</table>

**First Year**

<table>
<thead>
<tr>
<th>Program</th>
<th>991</th>
<th>991</th>
<th>991</th>
</tr>
</thead>
</table>

**Grand Total**

|                | 991 | 1113 (1) | 1119 (31) | 1220 | 5170 (333) | 143 | 9756 (365) | **Grand Total** |

**Not Included in the above figures**

<table>
<thead>
<tr>
<th>Program</th>
<th>23</th>
<th>15</th>
<th>10</th>
<th>30</th>
<th>208</th>
<th>-</th>
<th>284</th>
<th>NIH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Institute Harvard</td>
<td>16</td>
<td>12</td>
<td>11</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>57</td>
<td>MIT</td>
</tr>
<tr>
<td>Non-Institute Tufts</td>
<td>5</td>
<td>45</td>
<td>44</td>
<td>52</td>
<td>-</td>
<td>-</td>
<td>146</td>
<td>NIT</td>
</tr>
</tbody>
</table>

1Non-Resident Graduate Students

Not included in the above totals:
1 student in year two, 9 students in year three, and 3 students in year four on Foreign Study.
3 students in year three on Domestic Study.

*All figures include special students (special students also shown separately in parenthesis)*
<table>
<thead>
<tr>
<th></th>
<th>Professor</th>
<th>Administration and Programming*</th>
<th>Adjunct Professor</th>
<th>Associate Professor</th>
<th>Assistant Professor</th>
<th>Jr. Lecturers and Professors</th>
<th>Sr. Lecturers</th>
<th>Sr. Research Scientists</th>
<th>Instructor</th>
<th>Technical Instructors</th>
<th>Sr. Research Associates</th>
<th>Postdoctoral Associates</th>
<th>Research Assistants</th>
<th>Teaching Assistants</th>
<th>Instructor Corp</th>
<th>Total</th>
<th>Visiting Professors</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institute Professors</strong></td>
<td>12</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>School of Architecture and Planning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture</td>
<td>13</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>12</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>-</td>
<td>67</td>
<td>72</td>
<td>4</td>
<td>207</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Urban Studies and Planning</td>
<td>15</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>3</td>
<td>2</td>
<td>78</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>28</td>
<td>3</td>
<td>-</td>
<td>5</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>107</td>
<td>75</td>
<td>6</td>
<td>285</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td><strong>School of Engineering</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics and Astronautics</td>
<td>54</td>
<td>14</td>
<td>-</td>
<td>4</td>
<td>27</td>
<td>18</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>309</td>
<td>118</td>
<td>2</td>
<td>574</td>
<td>4</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>17</td>
<td>2</td>
<td>-</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>141</td>
<td>7</td>
<td>-</td>
<td>211</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>20</td>
<td>5</td>
<td>-</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>146</td>
<td>26</td>
<td>2</td>
<td>234</td>
<td>3</td>
</tr>
<tr>
<td>Electrical Engineering and Computer Science</td>
<td>54</td>
<td>14</td>
<td>-</td>
<td>4</td>
<td>27</td>
<td>18</td>
<td>5</td>
<td>-</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>309</td>
<td>118</td>
<td>2</td>
<td>574</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Materials Science and Engineering</td>
<td>17</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>1</td>
<td>15</td>
<td>195</td>
<td>16</td>
<td>-</td>
<td>272</td>
<td>3</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>26</td>
<td>4</td>
<td>-</td>
<td>3</td>
<td>12</td>
<td>4</td>
<td>8</td>
<td>26</td>
<td>1</td>
<td>-</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>258</td>
<td>29</td>
<td>1</td>
<td>388</td>
<td>4</td>
</tr>
<tr>
<td>Nuclear Engineering</td>
<td>15</td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>69</td>
<td>21</td>
<td>-</td>
<td>114</td>
<td>3</td>
</tr>
<tr>
<td>Ocean Engineering</td>
<td>13</td>
<td>1</td>
<td>-</td>
<td>7</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>52</td>
<td>9</td>
<td>-</td>
<td>96</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>184</td>
<td>35</td>
<td>-</td>
<td>8</td>
<td>86</td>
<td>64</td>
<td>21</td>
<td>15</td>
<td>60</td>
<td>6</td>
<td>15</td>
<td>5</td>
<td>36</td>
<td>1,104</td>
<td>264</td>
<td>5</td>
<td>1,109</td>
<td>19</td>
</tr>
<tr>
<td><strong>School of Humanities and Social Sciences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>28</td>
<td>-</td>
<td>73</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Humanities</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>28</td>
<td>-</td>
<td>73</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Anthropology/Archaeology</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Foreign Languages and Literatures</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>History</td>
<td>50</td>
<td>5</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>146</td>
<td>-</td>
<td>-</td>
<td>234</td>
<td>3</td>
</tr>
<tr>
<td>Literature</td>
<td>52</td>
<td>2</td>
<td>-</td>
<td>7</td>
<td>2</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>22</td>
<td>-</td>
<td>-</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Music</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Writing Program</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Linguistics and Philosophy</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Political Science</td>
<td>13</td>
<td>1</td>
<td>-</td>
<td>6</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Program in Science, Technology, and Society</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>68</td>
<td>12</td>
<td>-</td>
<td>1</td>
<td>44</td>
<td>23</td>
<td>5</td>
<td>52</td>
<td>-</td>
<td>1</td>
<td>13</td>
<td>-</td>
<td>81</td>
<td>53</td>
<td>2</td>
<td>355</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td><strong>Sloan School of Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>31</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>17</td>
<td>24</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>42</td>
<td>58</td>
<td>-</td>
<td>194</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td><strong>School of Science</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Biological Sciences</td>
<td>8</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>32</td>
<td>53</td>
<td>6</td>
<td>-</td>
<td>121</td>
<td>2</td>
<td>70</td>
</tr>
<tr>
<td>Biology</td>
<td>40</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>8</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>42</td>
<td>19</td>
<td>1</td>
<td>110</td>
<td>2</td>
<td>77</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>31</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>54</td>
<td>131</td>
<td>56</td>
<td>-</td>
<td>275</td>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>Earth, Atmospheric, and Planetary Sciences</td>
<td>19</td>
<td>2</td>
<td>-</td>
<td>6</td>
<td>11</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13</td>
<td>89</td>
<td>15</td>
<td>-</td>
<td>159</td>
</tr>
<tr>
<td>Mathematics</td>
<td>34</td>
<td>1</td>
<td>-</td>
<td>7</td>
<td>11</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>23</td>
<td>-</td>
<td>7</td>
<td>33</td>
<td>46</td>
<td>162</td>
<td>6</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>86</td>
<td>6</td>
<td>-</td>
<td>8</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>13</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>12</td>
<td>189</td>
<td>37</td>
<td>-</td>
<td>348</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>176</td>
<td>17</td>
<td>-</td>
<td>1</td>
<td>30</td>
<td>52</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>16</td>
<td>25</td>
<td>9</td>
<td>155</td>
<td>514</td>
<td>161</td>
<td>-</td>
<td>1,175</td>
<td>17</td>
</tr>
<tr>
<td><strong>Whitaker College of Health Sciences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology, and Management</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brain and Cognitive Sciences</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>16</td>
</tr>
</tbody>
</table>

**ACADEMIC STAFF COUNT**
<table>
<thead>
<tr>
<th>Administration</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force Aerospace Studies</td>
<td>9</td>
</tr>
<tr>
<td>Artificial Intelligence Laboratory</td>
<td>9</td>
</tr>
<tr>
<td>Athletic</td>
<td>2</td>
</tr>
<tr>
<td>Biotechnology Center</td>
<td>1</td>
</tr>
<tr>
<td>Center for Advanced Visual Studies</td>
<td>15</td>
</tr>
<tr>
<td>Center for Cognitive Science</td>
<td>15</td>
</tr>
<tr>
<td>Center for International Studies</td>
<td>8</td>
</tr>
<tr>
<td>Center for Technology, Policy, and Industrial Development</td>
<td>7</td>
</tr>
<tr>
<td>Center for Materials Research in Archaeology and Ethnology</td>
<td>1</td>
</tr>
<tr>
<td>Center for Materials Science and Engineering</td>
<td>10</td>
</tr>
<tr>
<td>Center for Space Research</td>
<td>5</td>
</tr>
<tr>
<td>Center for Transportation Studies</td>
<td>2</td>
</tr>
<tr>
<td>Clinical Research Center</td>
<td>2</td>
</tr>
<tr>
<td>Division of Comparative Medicine</td>
<td>4</td>
</tr>
<tr>
<td>Energy Laboratory</td>
<td>6</td>
</tr>
<tr>
<td>Experimental Study Group</td>
<td>15</td>
</tr>
<tr>
<td>Francis Bitter National Magnet Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Harvard-MIT Division of Health Sciences and Technology</td>
<td>40</td>
</tr>
<tr>
<td>Haystack Observatory</td>
<td>6</td>
</tr>
<tr>
<td>Laboratory of Architecture and Planning</td>
<td>15</td>
</tr>
<tr>
<td>Laboratory for Computer Science</td>
<td>17</td>
</tr>
<tr>
<td>Laboratory for Electromagnetic and Electronic Systems</td>
<td>10</td>
</tr>
<tr>
<td>Laboratory for Information and Decision Systems</td>
<td>6</td>
</tr>
<tr>
<td>Laboratory for Manufacturing and Productivity</td>
<td>6</td>
</tr>
<tr>
<td>Laboratory for Nuclear Science</td>
<td>5</td>
</tr>
<tr>
<td>Materials Processing Center</td>
<td>3</td>
</tr>
<tr>
<td>Media Laboratory</td>
<td>12</td>
</tr>
<tr>
<td>Medical Department</td>
<td>16</td>
</tr>
<tr>
<td>Military Science</td>
<td>149</td>
</tr>
<tr>
<td>Naval Science</td>
<td>6</td>
</tr>
<tr>
<td>Nuclear Reactor Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Office of the Provost</td>
<td>1</td>
</tr>
<tr>
<td>Operations Research Center</td>
<td>1</td>
</tr>
<tr>
<td>Plasma Fusion Center</td>
<td>14</td>
</tr>
<tr>
<td>Project Athena</td>
<td>67</td>
</tr>
<tr>
<td>Research Laboratory of Electronics</td>
<td>1</td>
</tr>
<tr>
<td>Sea Grant Program</td>
<td>21</td>
</tr>
<tr>
<td>Spectroscopy Laboratory</td>
<td>21</td>
</tr>
<tr>
<td>Statistics Center</td>
<td>5</td>
</tr>
<tr>
<td>Student Activities</td>
<td>1</td>
</tr>
</tbody>
</table>

Total: 515

Grand Total: 34

<table>
<thead>
<tr>
<th>Faculty Ex-Officis</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36</td>
</tr>
</tbody>
</table>

Note: Includes Administrative Officers, Affiliated Artists, Coaches and Trainers, Guests, Honorary Lecturers, Institute Organists, Visiting Lecturers and Senior Lecturers, Medical Doctors, Nurses, Postdoctoral and Research Fellows, Postdoctoral Trainees, Research Affiliates, Senior Research Engineers, Visiting Economists, Visiting Engineers and Senior Engineers, Visiting Research Associates, Visiting Scholars, Visiting Scientists, Visiting Writers. Total Teaching Staff 1,975. Not included in preceding total: Visiting Professors include 29 Professors, 21 Associate Professors, 11 Assistant Professors, 1 Institute Professor.
### WOMEN STUDENTS BY SCHOOL, COURSE AND YEAR, 1986-87

<table>
<thead>
<tr>
<th></th>
<th>UNDERGRADUATE</th>
<th>GRADUATE NON-</th>
<th>GRADUATE RESIDENT</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>REGULAR</td>
</tr>
<tr>
<td><strong>SCHOOL OF ARCHITECTURE AND PLANNING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture, IV</td>
<td>14</td>
<td>14</td>
<td>12</td>
<td>77</td>
</tr>
<tr>
<td>Architecture, IV-B</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Urban Studies and Planning, XI</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16</td>
<td>14</td>
<td>13</td>
<td>140</td>
</tr>
<tr>
<td><strong>SCHOOL OF ENGINEERING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeronautics and Astronautics, XVI</td>
<td>20</td>
<td>14</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>Aeronautics and Astronautics, XVI-C (Internship)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemical Engineering, X</td>
<td>19</td>
<td>20</td>
<td>22</td>
<td>33</td>
</tr>
<tr>
<td>Chemical Engineering, X-C</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Civil Engineering, I</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Civil Engineering, I-W (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Electrical Engineering and Computer Science, VI</td>
<td>47</td>
<td>31</td>
<td>32</td>
<td>94</td>
</tr>
<tr>
<td>Program 1-Electrical Science and Engineering</td>
<td>12</td>
<td>6</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Program 3-Computer Science and Engineering</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electrical Engineering and Computer Science, VI-A (Cooperative)</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Program 1-Electrical Science and Engineering</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Program 3-Computer Science and Engineering</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Materials Science and Engineering, III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Materials Science and Engineering, III-B (Cooperative)</td>
<td>3</td>
<td>24</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td>Mechanical Engineering, II</td>
<td>33</td>
<td>27</td>
<td>25</td>
<td>41</td>
</tr>
<tr>
<td>Mechanical Engineering, II-A</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Mechanical Engineering, II-B (Internship)</td>
<td>-</td>
<td>12</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Nuclear Engineering, XXII</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Ocean Engineering, XIII</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Ocean Engineering, XIII-A (Woods Hole)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Ocean Engineering, XIII-B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Ocean Systems Management, XIII-B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Center for Advanced Engineering Study, EN</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>164</td>
<td>167</td>
<td>154</td>
<td>320</td>
</tr>
</tbody>
</table>
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | 5 8 8 20 2 - 43  
|----------------------------------------|---------------------|
| Economics, XIV                        | 1 4 5 - - - 10      
| Humanities, XXI                       | - 2 4 - - - 6       
| Humanities and Engineering, XXI-E     | - 3 5 - - - 9       
| Humanities and Science, XXI-S         | 2 - 1 27 3 - 33     
| Linguistics and Philosophy, XXIV      | 2 3 3 42 13 6 - 69  |
| Political Science, XVIII               |                     |
| **Total**                             | 11 20 26 89 18 6 170|

| SLOAN SCHOOL OF MANAGEMENT            | 7 18 17 86 1 4 133  
|----------------------------------------|---------------------|
| Management, XV                        | - - - - - - - 133   
| Management Fellows, XV-A              | - - - - - - - 4     
| Management-Operations Research, XV-B  | - - - - - - - 6     
| Management-Ph.D., XV-P                | - - - - - - - 19    |
| **Total**                             | 7 18 17 115 1 4 162|

| SCHOOL OF SCIENCE                     | 82 86 76 264 3 3 514  
|----------------------------------------|---------------------|
| Applied Biological Sciences, XX        | - - - 43 2 - 45     
| Biology, VII                          | 31 40 26 51 - 1 149 |
| Biology, VII-A                        | 1 1 3 - - - 5       
| Biology, VII-B                        | 8 4 2 - - - 14      
| Biology, VII-W (Woods Hole)           | - - - 15 - - - 15   |
| Chemistry, V                          | 12 11 14 60 - - - 97|
| Earth, Atmospheric, and Planetary Sciences, XII | 1 8 6 24 1 - - 40 |
| Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole) | - - - 29 - - - 29 |
| Mathematics, XVII                     | 7 12 9 12 - - - 40 |
| Mathematics with Computer Science, XVIII-C | 8 2 3 - - - 13     |
| Physics, VIII                         | 10 6 11 30 - 2 - 59|
| Physics, VIII-A                       | 4 2 2 - - - - 8     |
| **Total**                             | 82 86 76 264 3 3 514|

| WHITAKER COLLEGE of Health Sciences, Technology, and Management | 1 4 6 14 - - 25  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain and Cognitive Sciences, IX</td>
<td>- - - - - - - 25</td>
</tr>
<tr>
<td>Health Policy and Management, HPM</td>
<td>- - - 1 - - - 1</td>
</tr>
<tr>
<td>**Harvard-MIT Division of Health Sciences and Technology, HST</td>
<td>- - - 4 - 12 - 16</td>
</tr>
<tr>
<td><strong>Undesignated</strong></td>
<td>22 13 - - - - 35</td>
</tr>
<tr>
<td><strong>First Year</strong></td>
<td>378 378</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>378 303 322 292 947 40 58 2,340</td>
</tr>
</tbody>
</table>

1 Also included in Classification of Students  
Total undergraduate women 1,295; 14 special undergraduate women are included.
### NUMBER OF DEGREES AWARDED IN SEPTEMBER 1986, FEBRUARY 1987, AND JUNE 1987

<table>
<thead>
<tr>
<th>S.B.</th>
<th>S.M.</th>
<th>M.Arch., M.C.P.</th>
<th>Engineer</th>
<th>Ph.D.</th>
<th>Sc.D.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>E E U</td>
<td>E E U</td>
<td>E E U</td>
<td>E E U</td>
<td>E E U</td>
<td>E E U</td>
<td>E E U</td>
</tr>
<tr>
<td>P B N</td>
<td>P B N</td>
<td>P B N</td>
<td>P B N</td>
<td>P B N</td>
<td>P B N</td>
<td>P B N</td>
</tr>
<tr>
<td>T E T</td>
<td>E T E</td>
<td>E T E</td>
<td>E T E</td>
<td>E T E</td>
<td>E T E</td>
<td>E T E</td>
</tr>
</tbody>
</table>

**SCHOOL OF ARCHITECTURE AND PLANNING**

| Architecture | - | - | - | 1 | 7 | 23 | - | - | 1 | 1 | - | - | - | 2 | 8 | 23 |
| Undesignated | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| Architecture Studies | - | - | - | 8 | 27 | - | - | - | - | - | - | - | - | - | - | 8 | 27 |
| Art and Design | - | 9 | 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | 9 | 16 |
| Planning | - | - | - | 2 | - | - | 5 | 9 | 36 | - | - | - | - | - | - | - | 5 | 9 | 38 |
| Real Estate Development | - | - | - | 35 | - | 1 | - | - | - | - | - | - | - | - | - | - | 35 | - | 1 |
| Urban Studies and Planning | - | - | - | 1 | 0 | 1 | 6 | - | - | - | - | - | - | - | - | - | 2 | 3 | 8 |
| Visual Studies | - | - | - | 10 | 1 | 6 | - | - | - | - | - | - | - | - | - | - | 10 | 1 | 6 |

**TOTAL**

| - | 9 | 20 | 45 | 9 | 35 | 6 | 16 | 59 | - | - | 3 | 4 | 7 | - | - | 54 | 38 | 121 |

**SCHOOL OF ENGINEERING**

| Aeronautics and Astronautics | 5 | 9 | 79 | 20 | 26 | 17 | - | - | - | - | - | 2 | 3 | 6 | 1 | 1 | 1 | 28 | 39 | 103 |
| Ceramics | - | - | - | 1 | 3 | 2 | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 2 |
| Chemical Engineering | 1 | 5 | 57 | 2 | 4 | - | - | - | - | - | - | 5 | 3 | 5 | 4 | 3 | 1 | 10 | 13 | 67 |
| Undesignated | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Chemical Engineering Practice | - | - | - | 9 | 13 | 12 | - | - | - | - | - | 9 | 13 | 12 | - | - | - | - | - | 1 |
| Civil Engineering | - | 2 | 12 | 5 | 21 | 37 | - | - | - | 1 | 4 | 3 | 3 | 5 | - | 1 | 1 | 11 | 26 | 69 |
| Undesignated | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Computer Science and Engineering | 8 | 12 | 79 | - | - | - | - | - | - | - | - | 8 | 12 | 79 | - | - | - | - | - | 15 | 15 | 212 |
| Electrical Engineering | 15 | 15 | 212 | - | - | - | - | - | - | - | - | 7 | 13 | 18 | 2 | 3 | 6 | 10 | 24 | 60 |
| Electrical Engineering and Computer Science | - | - | - | 25 | 34 | 107 | - | - | - | 1 | 9 | 7 | 13 | 14 | 19 | 1 | 3 | 1 | 40 | 60 | 134 |
| Electronic Materials | - | - | - | 4 | 1 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Materials Engineering | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Materials Science | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Materials Science and Engineering | 1 | 8 | 36 | - | - | - | - | - | - | - | - | 7 | 13 | 18 | 2 | 3 | 6 | 10 | 24 | 60 |
| Mechanical Engineering | 1 | 11 | 119 | 14 | 44 | 55 | - | - | - | 3 | 1 | 9 | 11 | - | 2 | 4 | 18 | 79 | 190 |
| Undesignated | - | - | - | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Metallurgy | - | - | - | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Naval Architecture and Marine Engineering | - | - | - | 1 | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Nuclear Engineering | 1 | 1 | 4 | 10 | 7 | 12 | - | - | - | 1 | 12 | 2 | 4 | 10 | 1 | 3 | - | 14 | 16 | 38 |
| Ocean Engineering | - | 2 | 8 | 2 | 1 | 5 | - | - | - | 1 | 2 | 2 | 2 | 5 | - | - | - | - | - | 5 | 5 | 20 |
| Ocean Systems Management | - | - | - | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Polymers | - | - | - | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |

**Total**

<p>| 34 | 64 | 630 | 93 | 158 | 280 | - | - | 3 | 13 | 26 | 37 | 61 | 79 | 9 | 16 | 14 | 176 | 312 | 1,029 |</p>
<table>
<thead>
<tr>
<th>SCHOOL OF HUMANITIES AND SOCIAL SCIENCE</th>
<th>Cognitive Science</th>
<th>Economics</th>
<th>Humanities</th>
<th>Humanities and Engineering</th>
<th>Humanities and Science</th>
<th>Linguistics</th>
<th>Philosophy</th>
<th>Political Science</th>
<th>Political Science, Public Policy</th>
<th>Psychology</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2 13</td>
<td>1 1 1</td>
<td>2 15</td>
<td>-</td>
<td>1 7</td>
<td>1 3 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>8 6 10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 3</td>
<td>2 1 3</td>
<td>1 6 9</td>
<td>3 9 26</td>
<td>1</td>
</tr>
<tr>
<td>58</td>
<td>9 9 24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>1 3 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3 15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>3 9 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6 10</td>
<td>3 15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>3 9 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>9 9 24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>3 9 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>23</td>
<td>3 15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>3 9 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>29 91</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- 1 3</td>
<td>3 9 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLOAN SCHOOL OF MANAGEMENT</th>
<th>Management</th>
<th>Management Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 39</td>
<td>1 9 6</td>
<td>14 23 262</td>
</tr>
<tr>
<td>12 14 256</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 10 58</td>
<td>2 6 10</td>
<td></td>
</tr>
<tr>
<td>13 13 23</td>
<td>19 29 91</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- 1</td>
<td>- 11</td>
<td>- 1</td>
<td>- 2 16</td>
<td>- 3 37</td>
<td>- 2 4 4</td>
<td>- 3 10</td>
<td>- 2 4 59</td>
<td>- 4 6 44</td>
<td>- 1 2 12 13 54</td>
<td>- 1 3</td>
<td>- 1 4 1</td>
<td>- 4 6 1</td>
</tr>
<tr>
<td></td>
<td>- 9 9 6</td>
<td>- 6 6 5</td>
<td>- 6 7 6</td>
<td>- 2 16</td>
<td>- 9 15 7</td>
<td>- 1 8 2</td>
<td>- 1 6 9</td>
<td>- 8 6 7 1</td>
<td>- 1 11 12</td>
<td>- 2 4 4</td>
<td>- 1 3</td>
<td>- 1 4 1</td>
<td>- 9 12 2</td>
</tr>
<tr>
<td></td>
<td>- 2</td>
<td>- 2 1 9</td>
<td>- 3 5 9</td>
<td>- 1 11 12 5 4</td>
<td>- 1 11 12</td>
<td>- 2 4 59</td>
<td>- 1 6 9</td>
<td>- 1 11 12</td>
<td>- 2 4 4</td>
<td>- 1 4 1</td>
<td>- 1 4 1</td>
<td>- 4 6 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 3 241</td>
<td>- 1 15 15</td>
<td>- 42 56 46</td>
<td>- 3 6 2 93 305</td>
<td>- 14</td>
<td>- 14</td>
<td>- 14</td>
<td>- 1 4 1</td>
<td>- 14</td>
<td>- 1 4 1</td>
<td>- 1 4 1</td>
<td>- 4 6 1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WHITAKER COLLEGE of Health Sciences, Technology, and Management</th>
<th>Cognitive Science</th>
<th>Brain and Cognitive Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of Technology</td>
<td>- 14</td>
<td>- 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Harvard-MIT Division of Health Sciences and Technology</th>
<th>- 2 - 3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Management of Technology</th>
<th>- 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations Research</td>
<td>- 1 4 4</td>
</tr>
<tr>
<td>Technology and Policy</td>
<td>- 5 6 11</td>
</tr>
<tr>
<td>Transportation</td>
<td>- 2 3 3</td>
</tr>
<tr>
<td>Without Course Specification</td>
<td>13 11 17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Awarded Jointly with Woods Hole Oceanographic Institution</th>
<th>Biology</th>
<th>Earth, Atmospheric, and Planetary Sciences</th>
<th>Electrical Engineering and Computer Science</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>- 1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>- 3 4 1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

| Grand Total | 49 108 1,002 | 184 226 659 | 6 16 59 | 3 13 26 | 101 149 166 | 9 17 17 | 352 529 1,929 |

|                  | 2 -         | - 9 9 24      | 3 15    | - 1 7    | - 1 3 14  | - 3 9 26 | - 1 1 3 9 |
|                  | 2 1 3       | 1 3 1         | - 1 3 1 | - 1 3 1  | - 3 9 26  | - 1 1 3 9 | - 1 3 1 9 |
|                  | 2 1 3       | - 3 9 26      | - 1 1 3 9 | - 1 3 1 9 | - 1 3 1 9 | - 1 3 1 9 | - 1 3 1 9 |
For fiscal year 1987, the total volume of sponsored research performed on campus approximated $262,754,000. This represents an increase of only 2.6% over fiscal 1986 volume of $256,096,000, the smallest year-to-year increase in the last ten years.

The breakdown by sponsor is shown in the following table:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEDERAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE</td>
<td>$20,934</td>
<td>$42,005</td>
<td>$49,562</td>
<td>$48,271</td>
<td>$56,363</td>
<td>$54,511</td>
<td>$55,062</td>
</tr>
<tr>
<td>DHHS</td>
<td>$19,140</td>
<td>$21,745</td>
<td>$28,977</td>
<td>$30,870</td>
<td>$40,252</td>
<td>$45,735</td>
<td>$47,310</td>
</tr>
<tr>
<td>DOD</td>
<td>$11,678</td>
<td>$15,224</td>
<td>$23,011</td>
<td>$31,883</td>
<td>$38,578</td>
<td>$43,418</td>
<td>$45,418</td>
</tr>
<tr>
<td>NSF</td>
<td>$21,469</td>
<td>$23,470</td>
<td>$29,913</td>
<td>$31,003</td>
<td>$33,658</td>
<td>$36,772</td>
<td>$38,091</td>
</tr>
<tr>
<td>NASA</td>
<td>$7,997</td>
<td>$9,504</td>
<td>$10,525</td>
<td>$10,445</td>
<td>$12,315</td>
<td>$12,864</td>
<td>$12,706</td>
</tr>
<tr>
<td>Other</td>
<td>$6,313</td>
<td>$9,043</td>
<td>$10,409</td>
<td>$10,400</td>
<td>$8,863</td>
<td>$7,823</td>
<td>$8,238</td>
</tr>
<tr>
<td>Federal Subtotal</td>
<td>$87,540</td>
<td>$120,991</td>
<td>$152,397</td>
<td>$162,872</td>
<td>$190,029</td>
<td>$201,123</td>
<td>$206,825</td>
</tr>
<tr>
<td><strong>NON-FEDERAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>$5,957</td>
<td>$8,150</td>
<td>$17,163</td>
<td>$19,753</td>
<td>$33,456</td>
<td>$36,290</td>
<td>$36,601</td>
</tr>
<tr>
<td>Nonprofit</td>
<td>$7,674</td>
<td>$9,538</td>
<td>$11,613</td>
<td>$13,196</td>
<td>$15,282</td>
<td>$15,532</td>
<td>$15,319</td>
</tr>
<tr>
<td>Other</td>
<td>$2,907</td>
<td>$2,627</td>
<td>$2,795</td>
<td>$3,452</td>
<td>$2,958</td>
<td>$3,151</td>
<td>$4,009</td>
</tr>
<tr>
<td>Non-Federal Subtotal</td>
<td>$16,538</td>
<td>$20,315</td>
<td>$31,571</td>
<td>$36,401</td>
<td>$51,696</td>
<td>$54,973</td>
<td>$55,929</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$104,078</td>
<td>$141,306</td>
<td>$183,968</td>
<td>$199,273</td>
<td>$241,725</td>
<td>$256,096</td>
<td>$262,754</td>
</tr>
</tbody>
</table>

Federal agency sponsorship increased by 2.8%. Department of Energy funding increased by only 1% over 1986, NASA decreased by 1.2%, and the remaining three major agencies increased at an average rate of 3.9%.

Of the non-Federal sponsors, industrial funding increased by .9%, continuing a downtrend from 40% in 1984, 21% in 1985, and 8.5% in 1986. In 1986, approximately $25 million of the industrial funding was provided by single sponsors of individual projects (including $5 million from foreign sponsors), and $11 million by multiple sponsors of consortia programs.

Support from private foundations and other nonprofit sponsors, which has been on a plateau in the last few years, decreased by 1.4%.
SIGNIFICANT DEVELOPMENTS

As in past years, a variety of continuing developments and new events had an impact on sponsored research programs. Among these were the following:

Restrictions on Scientific Communications

As noted last year, a White House directive and supplementing DOD guidelines have significantly reduced attempts by DOD contract officers to impose publication and other restrictions on DOD funded research involving so-called "critical" but unclassified technology.

Still pending at the close of 1986, however, were regulations designed to clarify restrictions on the presentation of scientific papers at professional society meetings. In addition, proposed revisions to the Department of Commerce Export Administration Regulations which would similarly exempt fundamental research from export control restrictions have not been issued in final form, and comparable revisions have not yet been proposed to the International Traffic in Arms Regulations administered by the State Department.

Federal Patent and Rights-in-Data Policy

We have noted in previous reports that the 1980 patent legislation providing university ownership of inventions resulting from Federally funded research has been a major factor behind the increase in university licensing programs.

In recent years, however, universities have argued that those licensing programs would be substantially more effective in transferring sophisticated technology if the same policy of contractor ownership were extended beyond patentable inventions to cover technical data and software as well.

An Executive Order on Facilitating Technology Transfer, designed to enhance U.S. competitiveness, was issued on April 10, 1987. It assigns the Office of Federal Procurement Policy within OMB the responsibility for coordinating the development of a policy which will provide for contractor ownership of technical data and software generated on Federally funded research.

Despite this, both DOD and the Federal civilian agencies, relying in part on their interpretation of recent procurement statutes, have issued new data policies inconsistent with the thrust of the Executive Order. How the issue will be resolved is not clear.

Increase in Regulations Affecting Research

During the last year, Federal agencies have issued a number of new regulations which directly affect the conduct and/or the administration of scientific research.

Several agencies have, for example, published regulations for reporting and handling allegations of misconduct in science. These have raised a number of issues, including how to ensure due process for the accused in view of the requirement that the anonymity of the informant be protected. Another example is the proliferation of regulations governing the use of human subjects and animals on research programs.

In addition, various statutes designed to curb abuses by large defense contractors and to ensure competition in the procurement of hardware and supplies have been applied equally to university contractors. Among other things, they limit reimbursement for the travel of contractor employees to the per diem rates applicable to Federal civilian employees; require the establishment of fraud, waste and abuse awareness programs on contractor premises, including training sessions and hotlines for reporting incidents; expand reporting requirements and compensation limitations with respect to the employment of former DOD procurement officials; and expand reporting requirements with respect to (1) subcontract activities which potentially benefit small businesses or minority and women-owned firms and (2) the hiring and promotion of disabled and Vietnam era veterans.

Foreign Funding of University Research

An increased interest in foreign support of research and other activities at American universities has resulted in a number of inquiries and articles in the media as well as reviews by the Federal government. During the year, for example, the General Accounting Office conducted a survey of foreign funding of research at selected universities, including MIT, and has scheduled on-campus visits in the fall of 1987 for the same purpose. In addition, the Higher Education Amendments of 1986 now require that educational...
institutions file an annual disclosure of gifts and contracts received from foreign sources. Similar requirements have also been adopted by a number of states.

Federal Efforts at Indirect Cost Reduction

We reported last year that, during 1986, NIH collaborated with the Office of Management and Budget in proposing a revision to the Federal cost principle that would establish a fixed ceiling on reimbursement of indirect costs for administrative functions at universities.

After prolonged negotiation with university representatives, OMB issued a revision to the cost principles of OMB Circular A-21 which limits the reimbursement of indirect costs for the administrative effort of faculty and department heads to 3.6% of modified total direct costs, i.e., 3.6 points in the indirect cost rate.

Shortly thereafter, several university associations, in collaboration, initiated a study of why indirect cost rates vary so widely between institutions. It is hoped that continuing differences between the universities and the Federal government over indirect costs will be narrowed if these variations are better understood. It might also lead to greater uniformity in rates, or in some components of the rate, to the extent that the variations result from accounting techniques rather than substantive differences such as organization and management philosophy.

Personnel Changes

During 1986, three assistant directors resigned to accept positions elsewhere — Sandra Buford accepted a position in private industry while Kathaleen Mercier and Rosanne Kumins accepted administrative appointments at Harvard University; Joseph Connolly resigned as Coordinator to become Administrative Officer at the Haystack Observatory; and Karen Hersey resigned as Intellectual Property Coordinator to accept a similar position at North Carolina State University.

Joining OSP were Bonnie Schaefer, who transferred from the Psychology Department to join OSP as Assistant Contract Administrator; William Barrett, who transferred from the Purchasing Office to join OSP as a Contract Administrator; Barbara Bruno, who joined OSP as a Contract Administrator; Patricia Greer, returning to OSP as a Contract Administrator; Diane Eisenhaur, who transferred from the Center for Space Research to join OSP as a Contract Administrator; and John Hynes, who left the Laboratory for Computer Science to return to OSP as a Coordinator. Also, during 1986, Charlotte Morse was the first individual to be promoted to Senior Contract Administrator.

GEORGE H. DUMMER
As we look back on the 1986-87 year we see many significant changes in the Institute's information systems environment: Project Athena began to convert its services from time sharing systems to workstations; Institute faculty and staff in their search for computational resources for their research continued to acquire minisupercomputers, used significant amounts of supercomputer time at the national laboratories and the NSF centers, and led the Institute to initiate consideration of the acquisition of an on-campus supercomputer; Institute faculty, staff, and students continued to acquire significant numbers of microcomputers and workstations for use in their offices, laboratories and dormitory rooms; Information Systems opened its on-campus Microcomputer Training Laboratory; and we marked the first full year of activities under the Institute's Strategic Plan for Administrative Information Systems.

As reported last year, the Strategic Plan represents a strategy for addressing the use of information technologies in support of the administrative and business activities of the Institute. During the past year the work of the plan has been undertaken by many individuals from all segments of the Institute with staff support from Information Systems.

Major accomplishments that were a direct result of the year's Strategic Plan activities include:

- The designation of two families of hardware -- one from Apple Computer and the other from IBM -- and software as standard administrative workstations. Application software to automate standard Institute administrative procedures such as wage and salary reviews, financial account analysis, budget preparation and submission, forms preparation and submission, etc. will be developed and implemented on these workstations over the next several years.

- The completion of a pilot program to provide limited electronic access by authorized individuals from departments, laboratories, and centers to the Institute's central employee data. The functionality of this pilot will soon be provided via the standard administrative workstations to administrative offices across the Institute. Over the next year, the functionality and availability of these services will be expanded.

- A pilot activity focusing on the functional analysis of a department's activities as a precursor to business automation has shown substantial promise with small departments and is now proceeding to examine one of the Institute's major central administrative departments. This activity will continue into the 1987-88 year.

- The Institute's Audit Division has appointed an EDP auditor as recommended by the plan.

- A training laboratory has been constructed in space previously housing mainframe terminals and equipped with IBM PCs and Apple Macintoshes. The courses offered in the lab are primarily for the Institute's administrative and support staffs and have proven to be so popular that the facility is expected to be at full capacity in a matter of months.

- Initial steps have been taken towards distributing the responsibility for administrative computing activities from Information Systems to the central administrative clients. Staff positions and responsibility for maintenance and support of some of the Institute's financial systems have been transferred to the Comptroller's Accounting Office. Transfers of funding from the Administrative Systems budget to the budgets of several administrative offices to support the purchase of development, maintenance, and support services will occur early in fiscal 1988. Our objective is to provide our central office clients greater management control of, and responsibility for, the use of computer resources which support their business functions.

These and other activities of the plan are discussed in the divisional reports.

Work on the installation of the Institute's new telephone system, an AT&T 5ESS PBX digital switch, has proceeded steadily throughout the year. Included in the switch installation is a major expansion of the Institute's computer
network, extension of our outside duct system to most campus buildings, and a completely new inside wiring system. The switch is expected to begin providing service in August 1988.

The transition between the 1987 and the 1988 fiscal years has also been marked by several organizational changes. Support of end-user computing is being focused within the Information Services division. To this end, major elements of the Departmental Systems and Client Service Center areas of Administrative Systems have been transferred to Information Services' Consulting Services group. As soon as space is available the PC Support group of Operations and Systems will join Information Services' Microcomputer Center. These changes are designed to make it easier for the consumers of Information Systems' services to access the organization's resources.

Plans were completed to create a new organization within Information Systems serving the large Institute community of DEC VAX users. The VAX Resource Center, which began its operation on July 1, 1987, will provide significant cost savings to those purchasing VAX maintenance services and software.

Another change separates the functions of development, maintenance, and support of major administrative application systems from activities associated with the development for an administrative computing infrastructure and staff support of the Strategic Plan. This change, which became effective July 1, 1987 has seen the formation of two divisions -- Administrative Systems Development (ASD), and Architecture and Strategic Technology (AST) -- using the staff and resources of Administrative Systems.

ASD will focus on the development, maintenance, and support of business applications for the central administrative organizations of the Institute, including support of the production databases. AST will have primary responsibility for the development of an administrative systems architecture; the investigation and selection of application development tools; leading an effort to develop standards and policies for information technology acquisition, use, and management; providing staff support for the strategic plan; and support of application programmers in ASD and the central administrative areas as they apply new tools and technologies.

The reports that follow highlight the activities in the four divisions that constitute Information Systems. Clearly, these brief reports cannot totally enumerate all the activities that have occurred or the care and effort that the staff take in exercising their responsibilities. Our sincere thanks go to all of these individuals for their work in Information Systems as well as to staff from across the Institute who have devoted significant time to the Strategic Plan for Administrative Information Systems.

**Personnel**

Information Systems continued its commitment to affirmative action during the 1986-87 year. In our searches to fill vacant positions particular attention was paid to identifying qualified under-represented minorities. However, success was meager. Efforts will continue during the coming year with additional emphasis placed on the identification of minority individuals for entry level positions where they can learn the skills required for more advanced positions. Information Systems was able during the year to continue to identify and attract a number of highly qualified women to its staff. At the present time, 45% of its professional staff are female.

A number of changes were made during the year in key leadership roles within Information Systems. Stephen M. Bayle joined the Institute staff as Director of Information Services. He will have primary responsibility for leading our efforts in the support of distributed computing on the campus. Donald E. Heller, Assistant to the Senior Vice President, was appointed to the new position of Director of Administrative Systems Development. William F. Hogue, Assistant to the Director of Project Athena, was given additional responsibilities as Director of the Athena Support Group, an organization which crosses the organizational lines of Project Athena and Information Systems to supply operational services to Project Athena. Marilyn A. McMillan, Director of Administrative Systems, was appointed to the new position of Director of Architecture and Strategic Technology.

JAMES D. BRUCE
CECILIA R. d'OLIVEIRA
ADMINISTRATIVE SYSTEMS

In fiscal year 1987 Administrative Systems (AS) achieved significant milestones in its application development, maintenance, and support services to clients in the central administrative community and explored possibilities for working with new clients, new technologies, and in new ways with existing clients. Central administrative databases reached rates of 50 to 60 million transactions per month for regular processing of admissions, payroll, personnel, pension accounting, financial, and ADDS (Alumni Donor Development and Schools) data. The transaction rates include production programs but also reflect both a growing use of databases for ad hoc inquiry by nontechnical staff in central offices and the beginning of central data access by department administrators.

Among major milestones several are particularly notable:

- Incorporation of staff payroll processing into the database environment already used for the hourly, biweekly, student, and voucher payrolls completed the integration of active employee payrolls into a single system. This enables more effective payroll administration, provides better information for all employees, permits more efficient response to changes in benefits policies and in government regulations, and constitutes the culmination of a several-year project.

- Designation of the hardware and software for the new Physical Plant system followed a period of intense software package and database evaluation. Their new system, based on a maintenance management package integrated with a relational database, will be brought online in phases over the next two years.

- An information needs assessment providing the groundwork for evaluating hardware and software for a new system for the Property Office has been completed. When fully implemented this new system will permit electronic distribution of property data to administrators throughout the Institute.

Exploratory efforts by AS staff this year also yielded important ideas about approaches to future services:

- In preparation for the coming Capital Campaign, AS staff worked with programmers in client offices to produce new reports and applications, to modify existing components of the ADDS database, and to design workstation networks. The Volunteer Control System, which allows designated campaign staff to coordinate database information about volunteer participants in the various solicitation efforts, is a successful product of this joint work.

- Transfer of responsibility for maintaining the new General Ledger system, from AS to programmers in the Comptroller's Accounting Office, began with CAO programmers taking primary responsibility for program changes to support the fiscal 1986 financial closings. This transfer of responsibility continued throughout the year, with AS involvement gradually, but significantly, decreasing below earlier levels.

- The VS1 Conversion project began this year initiating a two-year effort with participation from staff using and supporting systems in some twenty central offices. This project, which will be coordinated by AS, will eliminate the Institute's business dependence on an operating system which the vendor no longer supports.

- In the Strategic Plan for Administrative Information Systems' pilot programs, AS staff supported several new activities. For example, in the Accessible Employee Database (AED) and the Administrative Work Station (AWS) pilots, staff worked with members of the administrative officer community to define and exercise prototype systems for distributing central information to departments, laboratories, and centers for local processing. In the Budget Decentralization pilot, AS staff and clients explored options for providing application support to central offices that might offer clients more direct control of and responsibility for resources and priorities. In the Functional Analysis pilot, AS staff are participating in efforts to demonstrate the effectiveness of analyzing an office's business information needs before applying technology.

From these experiences it is clear that attention to application quality and productivity, to project management techniques and tools, and to data distribution technologies are vital focus areas as we continue to provide system development and support services to the administrative community.

MARILYN A. MCMILLAN
INFORMATION SERVICES

Information Services (IServ) continued to expand the scope of its products and services this year. Activities include participation in the Strategic Plan for Administrative Information Systems, new publications and seminars, a broadened product line in the Microcomputer Center, the creation of a training lab for microcomputers, and diversified consulting services.

The Microcomputer Center is in its third year of providing service to the MIT community. Systems available there include the Macintosh SE, Macintosh II, the enhanced versions of the IBM PC/XT and AT. Discussions are underway with IBM representatives regarding carrying their new line of personal computers, the Personal System/2. The Center, continuing to respond to customer requests, has added laser printing service for the IBM PC personal computers. Third party printers, memory boards, graphics cards, and monitors have been evaluated and stocked in response to customer interest. Improved response to customer calls has been achieved. New software packages and accessories are also being offered to our customers. Further, with help from the Office of Laboratory Supplies delivery time for personal computers has been reduced. As a result of these efforts, the Microcomputer Center has become an integral part of the microcomputer revolution on the campus.

Training Services opened the Microcomputer Training Lab in June. Hands-on training courses for IBM PC's, Macintosches and DECmates will be conducted in the Lab. Individual organizations can arrange for customized courses to be taught in the lab, or conduct their own presentations using the lab equipment. The lab is also open for practice sessions to anyone who attends a class or by referral from other Information Services groups. The Lunchtime Seminar Series continued on a quarterly basis with yearly attendance totalling over 2000 members of the MIT community.

During the past year Consulting Services has become more involved in administrative computing at the Institute. Where it once was strictly an academic and research computing organization, it now finds the majority of its clients to be from administrative offices. This is largely due to work in support of the Strategic Plan for Administrative Information Systems. Members of the staff have been active in both the Administrative Workstation and the Accessible Employee Database pilot programs. As the Institute moves away from mainframe computing to a community of distributed computing resources, staff resources must be leveraged. Thus, we have been actively involved in establishing user groups and have developed a set of hints and guidelines for such groups.

New directions for Information Services publications include developing marketing materials for Information System's products and services, and producing self-help manuals for microcomputer users. The i/s newsletter, created with desktop publishing software, has been well received in its first year; a brochure series, focusing on IS services, is being developed. New guides for microcomputer users include Guidelines for User Groups, Choosing a Microcomputer FORTRAN Compiler, and Data Acquisition. Other projects nearing completion are a training manual for the 5ESS digital switch, an updated SCRIPT manual reflecting the installation of Waterloo SCRIPT and a new release of IBM SCRIPT/VS on the MITVM systems, a new catalog of the MITVM help facility, and standard format guidelines for IS manuals, forms, and reports. Staff members also actively consult on electronic publishing issues.

STEPHEN M. BAYLE

OPERATIONS AND SYSTEMS

The activities of Operations and Systems (O&S) this year included a large variety of tasks which were performed to enhance the services provided to the client communities. New hardware installed included a Floating Point Systems (FPS) 364 which replaced the FPS-164 and a Digital Equipment Corporation (DEC) VAX 8550 which will replace a DEC VAX/785. Major efforts were involved in the conversion of Project Athena to a workstation environment.

In the IBM systems programming group (SPG), many of the activities were geared to improve services for the administrative client community and to improve the communications capabilities for all clients. A project was begun with AS and IServ to phase out the VS1 operating system. To accomplish this, SPG has worked on enhancements to the CMS and CMSBATCH systems to provide comparable functions to those offered by VS1. All of the functional designs have been completed and approximately one third of the new functions have been
implemented. Also, new packages to aid in the conversion have been installed. These included a new sort package as well as a system for storing and tracking changes in client production programs. Continuing efforts are being expended to enhance the security of the IBM systems. The VMSECURE package obtained last year was further tailored to improve the level of security offered on the IBM systems.

To improve data connectivity between the IBM systems and the campus computer network, a new release of the Wisconsin network code (WISCNET) was installed on MITVMA. A joint project with IBM to test and evaluate new hardware and software enabling better communications with the MIT network was begun during the year. Also, a project was initiated to replace the Memorex 1270 communications controllers with newer, more reliable programmable controllers. A NCR Comten 3695 processor was selected for this purpose and is scheduled for installation in the Fall of 1987.

Production Services has continued to improve its services to the administrative client community. New automated tools were developed to better track client output so that queries can usually be answered in minutes, rather than days, as with the previous manual system. A new rerun credit policy was implemented to permit automatic initiation of credits. Production Services continues to work with AS and SPG to provide better documented and more efficient systems. This has resulted in better support and faster turnaround to the client community with a smaller staff. On the average, production processing is now completed in a ten hour time frame on business days, compared to requiring the full 24 hour day plus time on most weekends in the past. This group is also very active in the VSI conversion project. A quality assurance effort has been established to work with AS to improve the overall quality of the applications portfolio.

The Athena operations support group has been very busy this year. The major ongoing activity was the deployment, installation, and support of the workstation environment and the migration of the VAX 11/750 timesharing systems to file service. Clusters in buildings 4, 11, 16, 37, E40 and W20 as well as five student living groups were converted to, or opened as, workstation clusters. Successful operation of these facilities required substantial effort and new learning by operations personnel during the year. The experience of the past year has proven invaluable in planning for complete system conversion in the coming year.

The facilities management group participated in the formation of the VAX Resource Center, an office that will provide new services for users of VAX computers on the MIT campus starting in July, 1987. The group also planned for and took delivery of a VAX 8550 as a replacement for the VAX 11/785 Accounts Payables and Purchasing System. This new hardware is scheduled to be brought online in July, 1987 to accommodate the expanded software system currently being developed as well as the expected tripling of the connected users. Revisions 4.4 and 4.5 of the VMS operating systems as well as revisions of other VMS layered products were installed on the VAX machines in W91.

ROGER A. ROACH

TELECOMMUNICATIONS SYSTEMS

MIT's new 5ESS digital switching system or PBX will be placed into service on August 12, 1988. The Institute's Centrex telephone service will be discontinued at that time, exactly sixteen years after it was originally placed into service.

Significant progress has been made towards the installation of the 5ESS during the year:

- New underground telephone ducts with new copper and fiber optic cables were installed on the West campus. In addition, work has begun in installing new underground telephone ducts under some public streets, increasing cable capacity between selected points on the campus as well as direct cable connectivity to buildings that are not currently connected to the duct system.

- Approximately 60% of the interior station wiring associated with telephone terminals has been completed.

- Training of the MIT community began, with approximately 400 individuals attending the first in a series of training classes. The purpose of these initial classes was to provide information about the new telephone instruments, and to gather information as to the type of telephone each user needs with the new system.
In total, MIT is installing over 500 miles of fiber optic circuits, 5,000 miles of station wire inside the Institute's buildings, and 18,000 miles of station wire outside its buildings in conjunction with its new phone system. The existing fiber optic cable plant associated with the MIT campus computer network was expanded to provide connectivity to W91 (the computer center) as well as to Project Athena installations in W71 (Next House) and Theta Delta Chi (fraternity). In addition, buildings 11 and 39 were cabled to provide local area network (LAN) connections in every room. Similar work has begun in buildings 13, 54, 66 and E25.

The campus computer network currently serves 673 computer systems located on 23 individual networks spanning 25 buildings. The network carries an average of 19 million data packets, including 3,000 electronic mail messages, per day.

MIT's video cable system was expanded to serve several new buildings. In addition, several dormitories are having video cable service installed in every student room in conjunction with the 5ESS wiring project.

On August 15, 1986, the Massachusetts Department of Public Utilities (DPU) issued a favorable ruling on a petition from MIT requesting that New England Telephone (NET) provide flat-rate residential trunk service to MIT dormitory residents. The DPU directed NET to provide such service via the MIT 5ESS PBX for student resident dormitory use.

This ruling is important not only for eliminating message units charges on calls placed by dormitory residents but because in its ruling the DPU recognized the diversity of communities within educational institutions. That is, both business and residential communities are included in an educational institution, and each is entitled to telecommunications services from local exchange carriers that specifically differentiate the two classes of use.

Currently, MIT student residents served by the Dormline telephone system have no local service and only limited access to toll or long distance service. With the installation of the MIT 5ESS PBX both local and long distance service will be provided with toll bills generated by the carrier providing the service. Costs associated with local service will be included in the rent for the dormitory room.

MORTON BERLAN
This year, several events took place that will have a major impact upon the quality of life of both students and staff in the years ahead. They were (1) the decision to increase the stock of graduate student housing, (2) the decision to proceed with the permitting and preliminary design phases of a 28 megawatt cogeneration facility, (3) the decision to vigorously pursue Cambridge Electric Company's new energy conservation rebate initiative program, (4) the purchase of the former TRW property at the corner of Main and Ames Streets, and (5) the purchase of the former F&T Diner and Cambridge Press properties on Main Street adjacent to the new Kendall/MIT inbound MBTA subway station.

This year also marked the completion of the first year of the management and operation of all food service facilities on campus by ARA Services, Inc. Although much was accomplished, a great deal remains to be done if our long-term goals are to be met. Planning for future food service needs remains a high priority. During the year, significant effort was expended on the planning and design of the new food service facilities that will be included in the renovated Stratton Center. In addition, a comprehensive feasibility study of the Faculty Club was undertaken in order to evaluate the full range of services that the Faculty Club could offer and the physical facilities that would be necessary to provide them.

In a renewed effort in the affirmative action area, each department was asked to summarize their past results toward meeting the objectives of the Institute's affirmative action plan. Each unit that reports to the Senior Vice President is strongly committed to this plan. Current statistics show that 18 percent of the positions held within this area are held by minorities and 24 percent by women. However, these positions are primarily within the support and service staff categories. For this reason, we have focused our affirmative action efforts on hiring individuals at the administrative staff and management levels and have tried to fill open positions with minority and female applicants. During the year, we have been successful in filling two openings with minority applicants -- one in the Campus Activities Complex and the other in the Office of Facilities Management Systems. As part of our overall effort, an extensive list of professional contacts has been identified as a resource to aid in the recruitment process.

Following are individual department reports.

WILLIAM R. DICKSON
During the year, efforts continued to be focused primarily on planning for the renovation of the Stratton Center. A marketing firm was retained to consult on marketing opportunities and retail design issues associated with the space; a local architectural firm was selected as project architect; and a student-based client team was appointed. Construction is scheduled to begin early next year with completion approximately 12 months later.

An extensive series of meetings were held throughout the year with various student and special interest groups to solicit input on the needs and problems that the renovation should address. In addition to the marketing study, a registration day questionnaire was administered in order to further identify the services needed in the building.

Areas to be renovated include the basement, first, second, and third floors with particular emphasis on expanded food services and improved aesthetics. Included in the design are new entrances; improved vertical circulation; enhanced emergency egress; upgraded fire alarm, smoke detection and sprinkler systems; a new service elevator; and revamped waste disposal, plumbing, heating, air conditioning, and ventilation systems. In addition, increased seating will be provided throughout the building in order to provide for the high demand experienced during dining hours as well as for casual lounging.

In other areas, a lighting and sound system study of Kresge Auditorium was completed. In the special events area, much time was given in support of the procedural changes which occurred in Commencement activities. Planning is currently underway to support the major Institute events scheduled next year in conjunction with the upcoming capital campaign.

STEPHEN D. IMMERMAN
In 1986, the MIT Campus Police Department continued to serve the MIT community with 24-hour professional police and emergency medical services. In addition, the Crime Prevention Unit and Special Services Division assisted the community by providing crime prevention education and informal legal advice and assistance for minor legal problems such as tenant/landlord disputes, consumer fraud, small claims court cases, abuse, and harassment situations.

There were a total of 1,902 complaints (situations which required the recording of an incident by police report) recorded this year, a 26 percent decrease compared to last year's figure.

Once again, larceny continued to be the most frequently committed crime on campus. Although Institute property dollar losses were up 5 percent to $87,639, personal property losses (non-residence) decreased 16 percent for a total dollar loss of $26,311. An important fact to note was a 62 percent increase in residence hall losses bringing this year's total dollar loss to $52,627 -- indicating the crucial need for implementation of the Housing Department's security upgrading and awareness program. Motor vehicle theft continued its downward trend on campus with a decrease of 9 percent from last year's figure or a total of 19 vehicles stolen in 1986.

Emergency medical service runs increased 4 percent for a total of 2,801 runs (including emergencies, transfers, and medical shuttles).

The Campus Police safety escort service provided 8,613 escorts, a decrease of 17 percent compared to last year.

JAMES OLIVIERI
Several major administrative changes occurred during the year, including the appointment of a Managing Director replacing the former General Manager. The administrative staff has been relocated back to the main house where they join the front office personnel to form one common area of general administrative activity. This relocation has greatly enhanced the efficiency of the staff.

Business activity continues to increase in both day and overnight categories. Positive financial results stemming from the new policy giving preference to residential group bookings are beginning to be observed. Although not all groups approve of this policy, financial constraints dictated that this policy be implemented.

Another step taken to generate income in support of the dining operation resulted in the application for a liquor license. A public hearing was held in April at which time the Dedham Board of Selectmen unanimously approved the application after neighbors and friends expressed their support of the facility. The Alcoholic Beverage Commission has approved the application and final approval from the Massachusetts Department of Revenue is now pending. It is expected that a license will be obtained by September.

Funding for capital expenditures still presents a challenge. During the year, the original boiler in the main house had to be replaced and an emergency generator was installed along with a new fire alarm system. In addition, an asbestos removal program has been initiated. A major capital project currently under review and one that cannot be postponed is the replacement of the original roof of the main house. In conjunction with this project, the existing lightning rod system will be replaced and all chimney caps will be repaired.

In an effort to increase revenues, the sales office initiated a program of direct sales calls to several local non-profit, health-related agencies and selected residential turnaways from the previous year. Some new business was generated from this effort and efforts will continue to generate business directed towards increased occupancy during slow booking periods.

From a statistical standpoint, Endicott House continues to have high utilization both from within and outside the Institute. Throughout the year, the Endicott House and adjoining Brooks Center were used 270 days and 198 nights by 173 different groups. This compares with 241 days, 179 nights, and 144 groups the previous year. Of these groups, 56 were MIT-affiliated business and 117 were non-MIT groups. There were 41 resident groups, compared to 29 last year, varying from an overnight stay to the nine week Senior Executive Program. Of these resident groups, 20 were from MIT versus 12 last year. There were 28,804 meals served and 7,609 room nights utilized throughout the year.

HOWARD F. MILLER
The dollar volume for all Graphic Arts services increased by seven percent this year. Once again, the largest increase occurred in the Institute Copier program, though at a somewhat slower pace than last year. The volume of work in the Copy Centers and the Offset Printing Department also increased substantially. Conversely, work in the Illustration/Typesetting Department decreased significantly as various MIT departments began using personal computers to produce original copy more frequently.

Video Production Services completed the first year of its two-year trial period in a very positive light, indicating it may well become an integral part of the services offered to the MIT community.

Renovations were completed on the second floor of the main Graphic Arts building, providing much needed office space and improving the customer/reception area.

Several pieces of new equipment were purchased, including the newest copy/duplicator from Eastman Kodak, the Kodak 300; eight other replacement copiers for the Copy Centers; and nine new copiers for the Institute Copier program. A new data system/mail machine was purchased for the Mail Service as well as an ATF two-color 17-inch press in the Offset Department.

JAMES W. COLEMAN
In April, the department moved its administrative offices to Building E32 from E18 where it had been located since 1964. The Off-Campus Housing Services and the Meal Plan Office, which still remain in E18, will be relocated to E32 sometime early next year.

The Faculty Club and food service units on campus have completed the first year of operation under the management of ARA Services, Inc. Much of this year has been spent in making the major transition from a self-operated system to one operated by a management company. Minor cosmetic improvements were made on all units; a major training program was conducted for the cooking staff, implementing new recipes and menus; and several management system components were installed. These changes have resulted in more flexible services and an improvement in the presentation of food to the community. The management and operating staff continue to seek new ways to work with different segments of the community in an effort to improve food services across the campus.

Planning for future needs in the Food Services area continued to be a priority this year. A significant effort was spent on the design phase of renovations to the Stratton Center food facilities. These renovations include work in the basement kitchen, originally designed to service about 60 percent of the business now being conducted, which will be expanded to meet the future daily dining needs and community catering requirements. In addition, a new food court facility replacing the Lobdell Cafeteria line and Twenty Chimney's will provide a variety of dining choices both in food and types of service. The food court will contain eight to ten stations offering selections of popular types of food.

Another major project undertaken this year was a feasibility study of the Faculty Club. This study evaluated the services which the Faculty Club might provide and the physical facilities that would be necessary to provide them. It is expected that a recommendation will be made early next year.

The Institute continues to strive to increase its stock of graduate student housing. Currently, there are two projects underway that will result in additional housing for a total of 60 graduate students. Renovations to the east wing of Ashdown House, when completed, will provide living accommodations for approximately 30 graduate students. The renovations also include a lounge and kitchen on this floor for the residents. This project is expected to be completed early next year. During the year, the Institute purchased nine condominium units in a complex located near the campus in East Cambridge. They plan to purchase an additional nine units early next year. These two purchases will house another 30 graduate students.

During the year, the department began upgrading the resident housing system security program. The department's objectives include gaining individual support for the program through an awareness campaign; substantially upgrading house security by repairing physical and structural changes in a more timely manner; installing a one-entrance desk control system in each house and then using clearance systems to control house access; and building a security network throughout the various campus departments to improve communications and response regarding security issues. A comprehensive analysis of the security needs for each house will be conducted throughout the entire system by the end of the year.

In addition to the usual painting and repair work carried out during the summer, the installation of a sprinkler system and the renovation of graduate assistant apartments in Baker House took place.

HARMON E. BRAMMER
The Office of Facilities Management Systems (OFMS) officially established the INSITE Consortium in 1976 as a means of sharing the software that OFMS had pioneered with various academic, business, government, and health-care organizations. Consortium members receive not only the software, but also applications support for their specialized needs and training classes held at the Institute. The members, in turn, exchange ideas and experiences with facilities management systems, which points the way to new requirements and new developments.

This office continues to audit MIT's physical space and maintain a current inventory on its database. Work on facilities management software continued with the introduction this year of the new INSITE-ANALYST program which is a decision-support tool that models data from INSITE or other sources hierarchically.

The local and national success of INSITE software led to invitations from the Japan Management Association in Tokyo and the National Institute of Higher Education in Dublin for the director to speak on the topics of facilities management in general and INSITE in particular.

This year's other educational activities included seminars to students during MIT's Independent Activities Program on the topics of careers in facilities management, computerized facilities management systems, and managing MIT facilities.

An INSITE cost and labor saving application for air filter replacement won national recognition when the National Association of College and University Business Officers (NACUBO) announced MIT as a winner in its annual contest. Thus, while international development has broadened the OFMS outlook, its Institute support activities have also grown and intensified.

KREON L. CYROS
Fluctuations in the cost of energy continue to present budget forecasting problems for the Plant. The price of oil dropped to $12 a barrel at the beginning of the fiscal year and closed out the year at just under $23 a barrel. This represented a recovery for fuel and electricity of roughly 40 percent of the price break experienced in FY 1986. Even so, campus energy costs were substantially under budget this year and projections for next year have been scaled down accordingly.

Because energy costs continue to be the major element in the Plant budget, efforts have been focussed on two important energy conservation projects. The first is cogeneration whose feasibility has been under study for several years. In the spring the Executive Committee of the Corporation gave approval to begin the permitting process and preliminary design for a combined-cycle cogeneration facility at the Central Utilities Plant on Vassar Street. Upon completion, this facility will generate 28 megawatts of power for sale to the utility and produce base load campus heating steam for most of the year. Projected savings over the life of the project are substantial and two of the older boilers will be taken out of service.

A second very exciting opportunity for energy conservation has been presented to the Institute by the Cambridge Electric Light Company's new conservation rebate initiative program. The utility will pay rebates to any customer who enters into a shared or guaranteed savings conservation agreement with a third-party developer. This program has a short implementation window and requires a substantial commitment in the time and resources of Plant but offers a high pay-off without any front-end capital. The Institute may realize rebates at the level of hundreds of thousands of dollars annually if the program works as presented. Negotiations were initiated with five energy conservation firms to prepare energy audits and cost-saving options for defined sectors of the campus.

The new Physical Plant on-line management information and financial control system moved into the development phase. Customization of vendor supplied software and other programming began with the first module, an operations center trouble-call and work order generating routine, scheduled to go on line next fall.

This year programs were initiated to address two potentially harmful environmental hazards. Working with Environmental Medical Services, the process of identifying the remaining asbestos containing materials on campus has begun with the intent of following up with a phased abatement program. In addition, identification of electric equipment containing PCB's and investigating the safest and most cost effective ways of removing this hazard is also underway.

Facilities Construction and Renovation

The Experimental Media Facility in the Wiesner Building was completed during the winter and several successful productions were held in the space this spring. On the West Campus, a new multi-use artificial turf playing field adjacent to the J.B. Carr Tennis Facility was installed. The air-supported enclosure for the Tennis Facility was replaced with a new air structure which has better insulating qualities, improved daylight conditions, and a longer projected life cycle than the old structure.

During the year, significant space renovation projects were completed in Building 7h for the Laboratory for Nuclear Science, Buildings 16 & 56 for Biology, and at 545 Technology Square, where spaces were prepared for robotics research by the A. I. Laboratory. The upper floor of the old Heinz Building on Vassar Street was renovated for use by Technology Review.

New projects initiated during the year include a major renovation of the Student Center space in the basement and first floor vacated by the Tech Coop plus dining and public areas on the second and third floors. A variety of retail stores and a new food court will be introduced along with improvements to circulation and public spaces. The former Hayden Art Gallery on the first floor of Building 16 is being converted to the Elizabeth Parks Killian Hall, a space where the School of Humanities and Social Science can schedule music performances, seminars, and other school functions. The basement of Ashdown House is being renovated into housing for 29 graduate students. An advanced Alcator research cell and supporting facilities are being constructed in the Nabisco Building on Albany Street.
Early in the fiscal year the Institute acquired the three acre TRV/Carr Fastener property at the corner of Ames and Main Street. After an evaluation of the old industrial buildings on the site, it was decided they were not suitable for conversion to institutional use. They will be demolished early next year and the land used temporarily for commercial parking.

**Building Operations**

A major modernization of the ten year old energy management system was substantially completed during the year. It involved the installation of 117 microprocessors in 34 high energy use buildings to replace original data concentration devices tied to a central computer. The new arrangement, which is similar to the system installed in buildings completed within the last five years, depends upon microprocessors to control each mechanical subsystem in the building rather than having all the devices controlled by a central computer. A new central computer is used only for monitoring and reset purposes.

This spring the Institute received a National Association of College and University Business Officers Cost Reduction Incentive Award for an Energy Effective Air Filtration program submitted by the Plant's Preventive Maintenance Section. The Office of Facilities Management provided computer support for this effort with its Insite space management program.

**Support Services and Building Maintenance**

Efforts were made this year in several areas to improve the condition of the grounds. A program of shrub and grass replacement was instituted on the main and east campus and parking lots at Eastgate/Sloan and Albany Street were repaved. The Hermann Building plaza and stairs were given a new concrete wearing surface.

A major masonry restoration project for the Buildings 7 and 10 domes was initiated in June. Damaged stone will be repaired or replaced, and caulking, roofing and other waterproofing measures will be carried out. In addition, repair of the limestone stairs at 77 Massachusetts Avenue also began in June.

The first phase of a program to identify and catalogue historical subsurface datum points including ground water survey wells and settlement pins was completed. This program which builds on the old Foundation Experimentation Research project (FERMIT) carried out by the Soils Engineering group of Civil Engineering in the 1960's and 70's will provide valuable data for monitoring the condition of the 6,000 wood piles which support the original campus buildings.

PAUL F. BARRETT
The Planning Office's activities this year reflect the development of its institutional research and planning capabilities, while continuing to provide the Institute with strong physical planning and community planning capabilities. Several major efforts involved all three aspects of the Office's mission, including a major study of Institute classrooms, a review of student and faculty housing site alternatives, the development of a strategic plan for office computer systems, and the continuing effort to provide administrative support to the Parking and Transportation Committee.

**INSTITUTIONAL RESEARCH**

The effort to develop a more integrated and comprehensive management and planning information system made excellent progress through Phase One of the Office's three year implementation strategy. The *MIT Factbook* was revised for FY 1986 and distributed to all departments and offices on campus. This statistical summary of the principle indicators of institutional growth and change is one of several anticipated planning and reference documents which will be made available to senior officers and to departments, laboratories, and centers.

Staff from this office were key participants in Pilot Program 4, part of the Administrative Systems Strategic Plan implementation. This program is developing a central employee information resource which will be accessible to authorized personnel at the departmental level. Major issues include system design, standards selection, security and privacy policies, planning for departmental training and support, database implementation and maintenance, and recommendations for cost allocation. Unlike many departments which require data for their own personnel only, the Planning Office has special information needs for gathering and analyzing statistical data from across the campus. Incorporating these requirements into developing systems will continue to be a concern of the Office.

Ongoing efforts of the institutional research staff include development of a computerized system supporting the Provost's Five Year Planning process, continued development of planning database systems, design of a comprehensive capital needs and planning document, and the development of an executive information system.

**PHYSICAL PLANNING**

A major study of MIT classroom facilities was prepared at the request of the Provost's Office in recognition of the current state of this resource and in anticipation of the Campaign for MIT. Other planning efforts included a review of housing site alternatives for students, faculty, and staff; preliminary planning for a proposed science complex, including a new building on the site of the former Carr Faster Division of TRW; and development of a Landscape Master Plan.

Efforts to improve the MIT landscape, as well as service access, and pedestrian circulation continued in cooperation with the MBTA and the City of Cambridge. Ongoing concerns include a pedestrian crossing at Ames Street, redesign of the parking areas servicing the Medical area and buildings along Main Street, and consultation on planning and development of the Student Center area.

**COMMUNITY PLANNING**

Events in Cambridge required our attention and coordinating efforts throughout the year. The completion of major elements of the Kendall Square urban renewal project have all had an impact on the Institute's immediate environment. These include the opening of the new hotel, the opening of the relocated Tech Coop, the new subway station, and the redesign of Main Street.

The University Park project on the former Simplex property and Cambridgeport continue to be a major subject of our attention. Continuing concerns include the effects of the environmental impact statement filed by Forest City Enterprises, developer of University Park, on traffic patterns and the quality of life in that area. We continue to monitor the Massachusetts Avenue and Harvard Bridge projects as well as many zoning and land use policy issues raised by community groups in Cambridge.

O. ROBERT SIMHA
Introduction

Implementation of changes necessitated by a new law changing the way workers compensation is administered by the Commonwealth was a major activity this year. As part of this effort, the Safety Office is supervising a management consulting firm retained to restructure MIT's present injury management system to make it more responsive and cost effective.

Education and Training

Safety education efforts continue at a high level with many departments refining their programs to suit particular needs. Efforts to cover new topics and bring in new speakers for seminars are currently being implemented and an audio visual presentation on material safety data sheets has been developed by the Safety Office.

Emergency Action Plan (EAP) program training continues to make progress, particularly in laboratory areas. The Athletic Department once again provided cardio pulmonary resuscitation courses for the Safety Office; however, interest in this activity has been decreasing in recent years.

Hazards Materials

The volume of waste chemicals generated was the same as last year. A new ventilation system and new storage racks were installed in the chemical waste storage building, 12A, greatly enhancing its capabilities.

Increased asbestos waste has necessitated installing a collection bin, similar to the one in Building E19, in the Central Utilities Plant.

The Safety Office staff has compiled information from other universities concerning how they handle spills of hazardous materials, what training is given to laboratory supply personnel, and what chemicals are available in plastic coated bottles. This information will be used to review the Institute's safety procedures.

Laboratory Safety

Safety committees continue to be active with most departments having inspection programs of their own or in conjunction with the Safety Office.

As a result of chemical spill incidents this year, an emergency spill response station has been established in Building 8 to contain materials and equipment necessary to handle hazardous material spills in the main group buildings. Emergency communications have been improved by purchasing two multichannel radios for Safety Office personnel to communicate with Campus Police, Environmental Medical Service, and Physical Plant.

Fire Protection

Several long-standing projects were undertaken this year. The Endicott House has a new fire alarm system and emergency generator and work is in progress to upgrade fire escape routes. Installation of sprinklers in Baker House is in progress and should be completed early next year.

Sprinkler systems were also installed in Buildings NW13 and NW21 and sprinklers for the Clinical Research Center are in the planning stage. Plans have also been submitted for new fire alarm systems in Buildings W16, W33, and 37. Buildings 13 and W23 have new fire alarm systems and improvements were made to the fire alarm systems in Buildings E17, 54, 56, NW15, NW21, W2, 3, and 10.

Safety Audits

As a result of EAP audits, potential polychlorinated byphenol (PCB) problems have been identified and action is in progress to eliminate them.

Also, potential electrical overload problems in the main group buildings are being identified and corrected.
Outside agency audits continue. No new problems have been identified and correction of minor deficiencies progresses.

Lincoln Laboratory

A Millstone Hill Safety Committee was established consisting of individuals representing Millstone Firepond, MIT, Lincoln Safety, and Environmental Medical Service. The purpose of this committee is to communicate and coordinate safety issues which affect the entire Millstone Hill community.

JOHN M. FRESINA
INTRODUCTION

The activities during the year were directed at preparing for the Campaign for the Future to be formally announced in October of 1987. These activities included an increased level of donor cultivation and solicitation which enhanced the level of gifts. The amounts received from gifts, grants and bequests and memberships in the Industrial Liaison Program reached a new high of $76.2 million, an increase of 21% over the results in the previous year.

The two major activities are divided into Resource Development-Gifts and the Industrial Liaison Program. Resource Development-Gifts has devoted considerable time during the year to staffing for the Campaign and continued efforts to identify qualified women and under-represented minority candidates. In this process, we were assisted by Barnes & Roche, fundraising counsel from Rosemont, Pennsylvania. They reviewed resumes, conducted interviews at MIT and throughout the country, brought candidates to our attention, and made recommendations on hiring for senior positions. During this period, sixteen have joined the staff of Resource Development-Gifts made up of eleven new hires and five transfers from other Institute departments consisting of six males and ten females. Included among these are Henry B. Barg '73, Director of Campaign Operations, Shelley S. Brown, Director of Campaign Systems, Judith M. Gooch, Director of Development for the School of Science, Frederick P. Gross '73, Director of Corporate Development, Elizabeth T. Harding, Director of Communications, Lucy V. Miller, Development Officer for Student Aid, and H. E. (George) Ramonat, Director of Major Gifts. There were several resignations and transfers to other departments during the year and the organization still had nine unfilled staff positions at year end.

PRIVATE SUPPORT

Private support for 1986-87 totaled $76.4 million, including the following: $68.3 million in gifts, grants, and bequests, and $8 million in support through membership in the Industrial Liaison Program. The total compares with $68.8 million in 1986, $68.5 million in 1985, $55.7 million in 1984, and $56.4 million in 1983. Gifts-in-kind for the past year (principally gifts of equipment) were valued at $25 million.

Sources of gifts for fiscal year 1987 were: alumni, $29.3 million; non-alumni friends, $5.3 million; corporations, corporate foundations, and trade associations, $17.1 million; foundations and charitable trusts, $16.3 million; and others, $0.4 million. Included in the totals for alumni and friends are gifts of $1.4 million made to the Rogers, Maclaurin, and Compton Pooled Income Funds. The total income of $8 million for corporate liaison programs increased 1% from the previous year.

Donors designated expendable and endowed funds as follows: unrestricted, $8.2 million; departments, $17 million; faculty salaries, $9.8 million; graduate student aid, $5.4 million; undergraduate student aid, $7.8 million; building construction funds, $2.3 million; and other funds, $17.8 million.

As a result of intensified solicitation activity over the past year, the Campaign Nucleus Fund has increased by $90.9 million, bringing the total to $172.7 million. It includes gifts and pledges for endowment and unrestricted purposes since July 1, 1984, and for all Institute purposes since January 1, 1986.

CAMPAIGN PREPARATIONS

The planning for the Campaign included both the setting of plans and priorities and the organizing of staff to carry it out. A key element of the Campaign is to increase the level of support from individuals and much of the staff additions are directed at this important goal.
Shortly after the beginning of the year, it was apparent that the Tax Reform Act of 1986 was going to cause considerable confusion for large donors considering important gifts to MIT and other charities in 1986 and 1987. In addition, the need to organize the effort to launch the Campaign made it difficult for us to reorient our efforts to adequately inform donors prior to calendar year end. The decision to postpone the formal start of the Campaign by six months to the fall of 1987 provided an opportunity to prepare a series of personalized letters, mass mailings, and detailed tax information to past donors. In coordination with the Alumni Association, these mailings took place in the fall of 1986 and again in June of 1987, and the response of donors both in their comments and gifts was very positive. The tax information on charitable giving prepared by Palmer & Dodge, legal counsel to MIT, in cooperation with the MIT Office of Planned Gifts and Legal Affairs, was cited by many as the best analysis they had seen.

The goal of increasing giving from individuals made it necessary to expand significantly our efforts to cultivate and involve important prospects. This included an increase in the number of events held both on and off campus for Campaign volunteers, donors and prospects. It also included an increased number of personal visits by key volunteers and senior officers with such individuals. These included the Campus Visits program, Sustaining Fellows activities, National Campaign area organization functions and the Corporate Leadership Awards event. Individuals also were involved through a variety of Corporation, Alumni Association, and school or departmental activities.

The management of MIT's relationships with corporations and foundations is divided among a large number of Institute offices, primarily depending upon the nature of the activity and the amount of direct involvement of faculty. During the year, we had success in gathering information on a wide variety of these relationships, and in organizing the information in a manner that could be used effectively by the Provost and other senior officers in overseeing and managing these activities.

The process of prospect management for individuals has been divided among three offices depending upon the potential giving capacity of the prospect. Major gifts was assigned responsibility for those prospects believed capable of Campaign gifts totaling $500,000 or more, the National Campaign Office for those prospects believed capable of Campaign gifts of $50,000 to $500,000, and the Alumni Fund for donors of smaller gifts. These activities are closely coordinated and such activities as Reunion Gifts managed by the Alumni Association are supported by the entire organization.

Managing information about gifts and individuals who are donors, prospects or volunteers is combined in a single ADDS (Alumni Development Donor System) database. Resource development devotes much of its efforts to identifying, qualifying, and tracking individual prospects for the Campaign. These efforts are primarily focused in Campaign Systems, although the process of tracking the most important prospects is assigned to Major Gifts. The Office of Development Services performs some of these functions for school-based fundraising efforts.

The plans for the Cambridge and New York City Campaign kickoff events are under the supervision of Mary Morrissey, Director of the Information Center, and Gayle Fitzgerald, Manager of Conference Services. They have considerable experience in successfully managing Commencement and other events on or near the campus.

The volunteer leadership of the Campaign was enhanced by the naming of Cecil H. Green '23 as Honorary Chairman. He joins Carl M. Mueller '41, John S. Reed '61, Joseph G. Gavin '41, Breene M. Kerr '51, and D. Reid Weedon '41 on the Corporation Campaign Committee.

OFFICE OF MAJOR GIFTS

The Office of Major Gifts is a new department in Resource Development organized under the direction of H. E (George) Ramonat in November 1986. Its main goal is to identify, qualify, and develop strategies for the face-to-face solicitations of alumni and friends of the Institute who have the potential to make a gift of $500,000 or more over a five-year period. All of these solicitations are scheduled to occur between January 1987 and June 30, 1992. The prime solicitors for these prospects will consist of senior officers of the Institute, faculty, and members of the Corporation Campaign Committee chaired by Carl M. Mueller.

Major Gifts officers are responsible for the management of the prospect pool. Each officer has regional responsibilities. Supporting these officers are two research teams headed by Assistant Directors of Major Gifts, Lois Graham and Margaret Gutowski. A database interactive tracking sheet was designed to drive the proactive prospect management system now in place throughout all of Resource Development.
One of the core needs of the Institute to be addressed by the Campaign is student support: $120 million is sought to support scholarships, fellowships, and other educational initiatives, such as the Undergraduate Research Opportunities Program. To focus more staff attention on this important area, Lucy V. Miller was appointed Development Officer for Student Aid. Her major responsibilities include providing informational support to other staff and volunteer fund raisers, and writing proposals for scholarship and fellowship support.

NATIONAL CAMPAIGN OFFICE

The main focus of the National Campaign Office (formerly Leadership Gifts) was the identification and recruitment of volunteer leadership throughout the country for the upcoming Campaign for the Future. Under the combined leadership of the Director of Campaign Operations, Henry B. Barg, and D. Reid Weedon, Chairman of the National Campaign Committee, the six District Directors were successful in recruiting 20 area chairmen and honorary chairmen, 23 vice chairmen, and identifying many more alumni who expressed their willingness to serve as solicitors on various area committees. In addition, Stanley M. Proctor '43 agreed to serve as a Vice Chairman on the National Campaign Committee with responsibility for non-alumni constituencies.

More thorough coverage of the Institute's key regional area was accomplished by the addition of two new District Directors in early fall: Marie J. O'Connor for the Mid-Atlantic and Southeast states and John W. Larson '80 for New England. They joined the other District Directors in providing comprehensive service to our volunteers and continued the qualification and screening of alumni with the capacity to make gifts of between $50,000 and $500,000 during the Campaign. Since 1984, 27 screening sessions have been held throughout the country (including six this year), where invited alumni gather to review lists of alumni that have been sorted by such categories as class, course, geography, living group, and profession. Alumni are rated as to their total philanthropic capacity over a five year period, as well as their feelings toward the Institute.

The informational needs of the District Directors for their volunteers have been met by the researchers of Campaign Systems and the programmers of Development Information Management Systems (DIMS). The Office of Campaign Systems has expanded its capacity to respond to the research requests of the District Directors, as well as to inquiries made from other areas of Resource Development and the Institute. In the same manner, the staff in DIMS is now providing custom computer-derived information reports within Resource Development.

The Sustaining Fellows Program continued to offer the Institute's most generous benefactors a number of events throughout the year as a way to recognize, involve, and cultivate them for future support. Frank S. Wyle '41 hosted a Los Angeles luncheon in September at which Professor Nicholas P. Negroponte was the guest speaker. Alex W. Dreyfoos, Jr. '54 and Wilfred D. MacDonnell '34 each hosted luncheons in Florida in February. Professor Richard J. Wertman was the speaker in Palm Beach and Chairman David S. Saxon '41 was featured in Naples. On Saturday, April 25, 1987, the Sustaining Fellows Program held a symposium in Cambridge titled "Extending Human Limits in Air, Sea and Space," moderated by Professor Jack L. Kerrebrock and featuring as speakers Professors Steven R. Bussolari, John M. Edmond, and Lawrence R. Young. Following the well attended symposium, 241 members and guests joined President Gray and Chairman Saxon for a formal gala at the Marriott-Long Wharf.

Breene M. Kerr '51, Chairman of the Sustaining Fellows since its inception in 1979, stepped down at the end of this year to take on new duties as Chairman of the Corporation's Investment Committee. Coincidentally, E. Barbara Lewis, Manager of the Program, resigned to be married and relocate to California.

Neil W. Didriksen, Director of Leadership Gifts, and Elaina M. Myrinx, District Director, resigned to assume positions at other institutions.

OFFICE OF CAMPAIGN SYSTEMS

The Office of Campaign Systems, directed by Shelley Brown, was created as part of the Development Office reorganization to provide research support to the Campaign effort through systematic prospect identification, qualification, and tracking. The office also has responsibilities for Campaign gift reporting and the monitoring of payments on gift pledges. Elizabeth Garvin and Dianne Overlan were promoted to Assistant Directors with responsibilities, respectively, for research and administration.
Over the past several months, a major effort has been made to strengthen the research process by streamlining formats and at the same time accessing more sophisticated research tools. Several hundred prospect information back-up reports were completed in support of the National Campaign Office, the Office of Donor Relations, and the Office of Foundations and Corporations. The office is at work to further computerize the research process to accommodate the anticipated need for more than 8,000 prospect profiles during the Campaign.

OFFICE OF DEVELOPMENT SERVICES

One of three separate groups established during last year’s reorganization of the Development Office, the Office of Development Services, headed by Dr. John E. Oldham, provides fundraising support to the Office of the Provost and the five academic schools. The group functions as an internal consulting unit, with assistant directors providing liaison between Resource Development and the assistant deans and directors of development within the schools.

The group’s major functions in preparation for the upcoming capital campaign include prospect identification and research, proposal writing, project management, and the development of solicitation and cultivation strategies.

Recent principal development activities within the School of Engineering include an $8 million endowment campaign for the Chemical Engineering School of Practice; fundraising for the Commission on Manufacturing and Productivity, and the Minority Introduction to Engineering and Science (MITES) program; and a major initiative in the field of manufacturing research and education.

The School of Science has begun raising funds for a new Science Complex, a memorial chair in Physics, graduate fellowships, and specific department needs. The School of Humanities and Social Science has focused on funding for The International Security and Arms Control program and the undergraduate education initiative. The School of Architecture and Planning has been intensively engaged in prospect identification and cultivation. The major capital project of the school will be renovation of the Rotch Library.

Provost John M. Deutch will direct a number of important Campaign initiatives. John Jacoby assists the Provost and his staff in their fundraising efforts and will undertake projects endorsed by the Campaign Priorities Group that extend beyond the boundaries of any individual school, yet are related to the academic priorities of the Institute.

Dr. Oldham was appointed Director in November, Lisa Hiley was promoted to Assistant Director, and Dr. John Jacoby, formerly Associate Director of Development at Amherst College, was hired as Assistant Director. Assistant Director Nancye Mims held a similar position in the former Development Office. Phyllis Gallant has been serving as Assistant to the Director since April 1, but will be retiring September 1.

CORPORATE DEVELOPMENT AND OFFICE OF FOUNDATIONS AND CORPORATIONS

An Office of Corporate Development was established under the direction of Frederick P. Gross. Its primary objectives are identification, assistance in cultivation, and tracking of major corporate prospects. During the past year, 127 companies were identified as major prospects (potential for Campaign support of greater than $1 million).

Major attention in the Office of Foundations and Corporations was given to reviewing and monitoring strategies for approaches to 40 major foundations. This project, headed by Vincent C. DeBaun, was based on specific academic priorities established in the Office of the Provost.

Teams of officers from several major corporate prospects visited the campus. Programs arranged for them included opportunities to meet with graduate students in their areas of interest, receive research briefings from faculty, and have discussions with the Institute’s President, Chairman or Provost.

On April 24, 1987, Corporate Leadership Awards were conferred on 64 alumni. The Award honors individuals whose responsibilities in private industry as leaders of their companies mark them as exceptional contributors to the strength and well being of economic systems. The Corporation initiated the Awards in 1976 and presentations were also made in 1977, 1978, 1980, and 1984. The April 24 event differed from those held previously in that it was broadened into a special day-long...
tenth anniversary celebration to which 248 former Award recipients were invited, together with members and former members of the Corporation, and their spouses. Total attendance was 215. It was a successful undertaking which offered a unique opportunity to develop closer relationships with prominent alumni. The program was supervised by Robert Hagopian, who also continued his activities in support of the National Business Committee.

DONOR RELATIONS AND CAMPUS VISITS

Under the direction of Martha Bertrand, the Office of Donor Relations and Campus Visits completed its first year of operation. Joining the office in September 1986 were Leslie Cariani, Donor Relations Coordinator, and Cassandra Page, Campus Visits Coordinator.

Donor relations activity concentrated on intensifying existing programs of stewardship and donor recognition. Citations were prepared for presentation to several donors, and plans were completed for donor recognition gifts to be mailed during the summer of 1987.

The Campus Visits section ran MIT's first five visits. Two fall visits and one spring visit focused on a variety of Institute activities, while two spring visits focused, respectively, on the School of Engineering and the School of Humanities and Social Science. The programs were well received and planning is underway for several visits in the 1987-88 school year.

CORPORATION DEVELOPMENT COMMITTEE

The annual meeting of the Corporation Development Committee (CDC) was held on November 6, 1986 with Chairman David S. Saxon presiding. This meeting, attended by 51 members, plus special guests and members of the Institute staff, marked the twenty-second year of operation for this alumni group. The meeting focused heavily on the upcoming capital campaign and the need for strong volunteer participation in order to achieve success. The program included a panel on undergraduate education at MIT. In the course of the meeting, Chairman Saxon introduced Joseph S. Collins, who will serve as the new Executive Officer of the CDC. Mr. Collins continues as Director of the MIT Alumni Fund.

The recipient of the Marshall B. Dalton '17 Award was Kenneth J. Germeshausen '31, a member of the CDC since 1969 and a life member of the MIT Corporation. He was cited for "more than 50 years of outstanding service to MIT."

With deep regret, the CDC noted the death of five of its members: Marvin A. Asnes '49, Jonathan Y. Ballard '23, Earle A. Griswold '23, Clint W. Murchison, Jr. '44, and John L. Riegel '19.

COMMUNICATIONS

In February, Elizabeth T. Harding joined the Office of Communications as Director, succeeding Deborah J. Cohen, who became Assistant Dean of Development in the School of Architecture and Planning. During the year, the staff produced a series of publications, including Educating Tomorrow's Leaders: Student Financial Aid at MIT; MIT Facts 1987; a revision of Perspectives on MIT; two issues of the CDC News; and a Sustaining Fellows newsletter, as well as an array of proposals to individuals, foundations, and corporations. The CDC News won a CASE (Council for Advancement and Support of Education) silver medal in the newsletter category in 1986.

Work on the upcoming capital campaign commenced in the summer of 1986. Carr Associates, headed by a former head of the MIT Office of Communications, helped to develop an overall plan to guide decisions on publications throughout the five-year campaign. Working from the plan, the staff wrote the first Campaign document, a prospectus describing the drive's objectives, organization, and strategy. Carr Associates was asked to prepare a volunteer handbook and the casebook. Two other outside consultants were employed. Logowitz and Moore created the Campaign logo, and Image Presentations undertook the preparation of a multi-image slide presentation to be shown first at the Campaign kickoff in October.
INFORMATION SYSTEMS

During this year of planning and changes necessary in anticipation of the Campaign announcement, preparation of the information systems continued.

Two new applications utilizing the ADDS Database on the mainframe were put into production for use by the fundraising staff of Resource Development, the Alumni Association, and the School Development Officers. The first application, Volunteer Control, provides information support for recruiting and recording assignment of volunteers to specific solicitation programs for the Campaign. The second application, Prospect Tracking, provides information about identified prospects and the staff assigned to each prospect. Modification to the existing Prospect Control application was coordinated by Gregory Whall, Administrator of DIMS, working with a consultant, The Cadence Group.

Administrative Systems staff of MIT Information Systems have provided the programming support to produce management reports specified by Campaign Systems, utilizing the ADDS Database. This group in Administrative Systems has also provided programming for data entry and reports to support preparations for the Campaign kickoff.

The information services provided by DIMS now include programming, report production, training and equipment maintenance support to the entire Resource Development and school development officer organization.

A series of seminars were presented during the year by Barbara A. Durland, Assistant to the Vice President and Treasurer for Information Systems, to acquaint staff with the data available in the ADDS Database.

INDUSTRIAL LIAISON

The past year saw a major strengthening in the Industrial Liaison Program's relationships with MIT faculty, departments, and research organizations, and a record revenue stream of $8.1 million. Directed by Professor James M. Utterback, the Program has a membership of 293 companies, including 176 in the United States, 58 in Europe, 51 in Japan and 8 elsewhere.

In consultation with the Faculty Committee on Industrial Liaison, the Program updated its policy to encourage the creation and growth of a broader base of MIT industrial collegia. In consultation with the Deans of the Schools, Program priorities and activities have been chosen to reflect the broader priorities of the Institute. Program staff have undertaken a major effort to strengthen ties with U.S. companies in support of Resource Development activities. A new Faculty Guide to Industrial Liaison at MIT was issued.

In the face of increasing competition from other universities, the Industrial Liaison Program is emphasizing the customized aspects of its relationships with member companies, while maintaining the quality of its standard offerings. The number of company-specific research briefings held on campus increased significantly this past year. In all, the Program hosted 1,069 visits to campus, and arranged 562 visits to company locations worldwide.

During the academic year, the Program presented a spectrum of symposia on industrially relevant topics, including "Computing and the Senses," in collaboration with the Media Laboratory and Alumni Association; "Applied Biological Sciences," an inaugural two-day meeting highlighting the newly formed department; "Hazardous Substance Management: The MIT Perspective," in collaboration with the Hazardous Substances Initiative; and "The Manufacturing Science and Technology of the Future," with the Laboratory for Manufacturing and Productivity and National Science Foundation. Overall, the Program series of 12 symposia attracted more than 2,000 attendees.

The Program continued its series of on-site seminars, holding 29 half-day meetings at company locations throughout the U.S., Europe, and Japan. We look forward to increasing this number in the coming year, focusing especially on U.S. locations.

The MIT Report earned another accolade, capturing a bronze medal for Periodical Resource Management from CASE. It was broadened to include a Viewpoint column, which presents the opinions of senior industrialists and government officials on matters of science and technology policy and strategy.
David A. Woodruff and David R. Lampe were each promoted to the position of Assistant Director of the Industrial Liaison Program. Marc J. Chelemer, Christopher F. Dippel, John W. Leech, and Kevin E. Lonnie were each promoted to the position of Senior Liaison Officer. June A. Lipnoski was promoted to Manager of Information Services for the Program, and Philip J. King was promoted to Publications Supervisor. The following new officers were appointed: Carl C. Accardo, Jiro Adachi, William J. Culbert, Howard E. Engelson, Cynthia D. Lubien, David Marsh, and William R. Ramsey.

Resignations were received during the year from: J. Peter Bartl; Carmen R. Besterman, to relocate to Switzerland; Frederick P. Gross, to accept a position as Director of Corporate Development; Norma Henderson, to start a private consulting practice; W. Scott Johnsen, to accept another position; Jennifer Knapp-Stumpp, to become a full-time mother; Linda K. Smith, to accept a position with a consulting firm; and Seichi Tsutsumi, to accept another position.

GLENN P. STREHLE
The Alumni Association is a reflection of MIT and its alumni. It is not surprising that we are driven. This year alone volunteers and staff wrote and approved a new constitution, broke all previous Alumni Fund records with $13.7 million raised, and held yet another successful off-campus National Alumni Conference. We began work on a new financial system at the urging of the Audit Committee of the Board of Directors. The staffs in New York City, the Technology Review, the Enterprise Forum, and the Reunion and Special Events have moved into new locations. We now have a series of networked Macintosh computers linked to our IBM mainframe which is slowly enabling us to move forward with computer linkages outside of MIT. Technology Review was honored again this year as a finalist in the national magazine awards from the Magazine Publishers Association. Finally, many of volunteers and staff members alike have begun to be involved, and some might even say consumed, with campaign activity.

This fast-paced year demanded the critical leadership of key volunteers. We were truly fortunate this year to be led by people with vision and energy. Key among them were Joseph G. Gavin, Class of 1941, President of the Alumni Association, Harris Weinstein, Class of 1956, Chairman of the Alumni Fund Board, and another yeoman effort by E. Milton Bevington, Class of 1949, Past President of the Association, who chaired the Audit Committee of the Board of Directors. Special recognition should be given as well to the leaders of the Classes of 1937, 1947 and 1962 including Joseph F. Keithley '37 and George S. DeArment '37 and their reunion chairman G. Richard Young '37, and Harl P. Aldrich '47 and Claude W. Brenner '47 and their reunion chairman Robert L. Horowitz '47, and Ed Linde '62 and his reunion chairman Bardwell Salmon '62, for their record-breaking reunion's gift activity. Volunteers, over 4700 of them, enable this small hardworking staff's efforts to be leveraged superbly. During the upcoming campaign even more alumni need to be involved and become committed to MIT.

The staff of the Association grew considerably as we scaled up for the campaign. John Blake joined the staff as Director of Information Management reporting to the Executive Vice President. Numerous other additions and promotions are detailed in the individual summaries.

As always the close of a year of great success brings with it the anticipation of an even more successful ensuing year. Given the challenges and ongoing support the Alumni Association looks forward with relish to FY1988.

Alumni Relations

The National Alumni Conference was held in Southern California this year. A series of workshops were presented which were aimed at helping alumni in all of their volunteer roles. President Paul E. Gray '54 and his wife Priscilla, an Honorary Alumna, attended the entire conference. The program, "Computing for the Senses" featured speakers from the Jerome B. and Laya Wiesner Media Laboratory. Led by Nicholas Negroponte '66, Director, the speakers included: Stephen Benton, Andrew Lippman, David Zeltzer, Richard Bolt, Christopher Schmandt, all from the MIT Media Laboratory.

Technology Day, June 5, 1987 focused on Project Athena and UROP. Professor Steven Lerman '77, Director of Project Athena was the moderator. Speakers were Joseph Ferreira, Jr. '67, Urban Studies and Planning, Joseph Smith, Jr. '59, Mechanical Engineering, Gilbert Russo '87, Mechanical Engineering, Janet Murray, the Writing Program at MIT and three UROP students involved in these programs.

Reunion programs brought over 1200 alumni and guests back to campus for four days of reminiscence and camaraderie. Alumni representing fourteen reunion classes, 1917 through 1982 were present. Activities took place both on campus and in locations such as Thompson Island and the John F. Kennedy Library.

The Alumni Council convened six times over the course of the past year, usually on the last Monday of the month. Guest speakers included Royce Flippin, Barry Vercoe, Harold Edgerton, Franco Modigliani, Charles Cooney and David Hardt. The Council continues to feature a "sponsor a student" program where alumni are encouraged to pay for students' attendance.

The Boston Seminar Series convened six times over the course of the past year, usually the first Monday of the month. The program theme was "Exploring Modern Africa." Guest speakers included Robert Rotberg, MIT, William Cotter, Colby, John Harris, Boston University, William Griffith, MIT, Donald Easum, African American Institute, and Willard Johnson, MIT.

AMITA (Association of MIT Alumnae) activities are varied and take place throughout the year. The highlight of AMITA's calendar is the annual conference, usually held in mid-March. This year's conference was entitled, "How Do You Spell Success." Other AMITA activities over the year included: the Annual Senior Academic Award, conferred on two graduating women students; a Talbot House Weekend Retreat; a telethon.
for the AMITA Scholarship Fund; and an annual meeting at Endicott House.

BAMIT (Black Alumni of MIT) has two regularly scheduled programs over the course of the year; one is its newsletter, published four times a year, the other is the Annual Black Students' Conference on Science and Technology. The conference traditionally opens with a 'Career Showcase' in which 25-30 companies send representatives to speak to students about prospective employment.

The Board of Directors approved the following recommendations of the Awards Committee:

**Bronze Beaver Awards:** W. Gerald Austen, Class of 1951; Susan L. Kannenberg, Class of 1961; Joseph F. Keithley, Class of 1937; Charles E. Kolb, Class of 1967; John S. Reed, Class of 1961; and Emily V. Wade, Class of 1945.

**The Harold E. Lobdell, Class of 1917 Distinguished Service Awards:** Karen Arenson, Class of 1970; Elda Chisholm, Class of 1949; Jorge Diaz Padilla, Class of 1974; John A. Hrones, Class of 1934; Shirley Jackson, Class of 1968; Stanislav Jakuba, Class of 1970; John Kunstadter, Class of 1949; E. Hibbard Summersgill, Class of 1936 (deceased December 14, 1986); Barry Unger, Class of 1969; and Bennett Zarren, Class of 1961.

**The George B. Morgan '20 Awards:** Eugene Ashley, Class of 1948; Arthur Katz, Class of 1961; Samuel Losh, Class of 1954; James Maguire, Class of 1938; George Revell, Class of 1935; and Donald Steig, Class of 1955.

**Presidential Citation Awards:** Boston Seminar Series: Africa Seminar; MIT Class of 1961 Reunion and Gift Committee; MIT Club of Switzerland; MIT Club of Northern California (for sustained excellence); MIT Enterprise Forum of South Texas-Economic Development Panel.

**Honorary Membership in the Alumni Association:** Winifred T. McDonough; Dorothy G. Adler.

The following alumni were elected by national ballot to serve three-year terms on the National Selection Committee: Christina Jansen, Class of 1963, District #1; David W. Weiss, Class of 1952, District #5; Louis F. Kreek, Jr., Class of 1948, District #6; John A. Hrones, Class of 1934, District #7.

The National Selection Committee made the following selections for terms starting July 1, 1987:

**Elected to the MIT Corporation:** E. Rudge Allen, Class of 1948; John K. Castle, Class of 1963; Walter J. Humann, Class of 1959.

**Elected President of the Alumni Association:** Raymond S. Stata, Class of 1957.

**Elected Vice Presidents of the Alumni Association:** Robert H. Muh, Class of 1959, Peter Saint Germain, Class of 1948.


**Alumni Fund**

The Alumni Fund, chaired by Harris Weinstein, Class of 1956, achieved new milestones in its continuing tradition of record-breaking performance. Reporting contributions in the amount of $13,686,000 from 27,791 alumni, the Fund in 1987 marked the thirteenth consecutive year of dollar increases and the eighth year in the past nine of new million dollar plateaus, combined with a new record for alumni participation. In fact, the dollar total exceeded last year's figure by $2.5 million or 22% and jumped one million-dollar plateau.

While it is difficult to pinpoint all the factors contributing to this success, several are worthy of note. Broad-based participation in the Alumni Fund continued, with 48% of undergraduate alumni making a contribution, together with 31% of the graduate alumni. Upgraded support exceeded all prior levels with 1200 alumni representing 4.3% of the contributors giving $1000 or more, some 4300 or 16% contributing $250 or greater and 10,400, a one year increase of 1000 alumni, making a contribution of at least $100. The increase to 38% in the number of alumni giving at the $100 or greater level suggests that the Fund may achieve a median gift of $100 sooner than targeted.

This year was one of transition for the staff, as management and program assignments changed in anticipation of the major fund-raising campaign to be launched in Fund Year 1988. The staff is now organized in four program teams: major reunion gift, personal solicitation, volunteer intensive and staff intensive programs. Several staff members were added while others changed assignments during the year and it is a tribute to their collective professionalism that the Fund was able to achieve such satisfying results. A detailed report follows.
The Major Reunion Gift Program has had a very successful year. The 25th, 40th, and 50th Reunion classes presented to the Institute on Technology Day gifts totaling nearly $10.5 million, 48% over last year's three class total. The 50th Reunion Class of 1937 raised $4,787,067, the largest 50th Reunion Gift in recent years, and announced an additional $1,827,000 in intended future gifts to MIT. The Class of 1947 presented a record-breaking gift of $3,007,201, of which $443,000 has been designated to the Class of 1947 Professorship. The Class of 1962 raised $2,661,476, an increase of more than 20% over the previous 25th Reunion Gift record. Of this total, gifts of nearly $250,000 have been designated to the Class of 1962 Permanent Endowment for Student Financial Aid. These campaigns include all gifts and pledges made in the five years prior to the reunion; pledges are payable over the five years following the reunion.

Also announced on Technology Day were gifts from the 60th and 65th Reunion Classes. These campaigns include only gifts and pledges made in the five years prior to the reunion. The Class of 1927 raised a total of $2,169,367, and the Class of 1922, $2,013,890 with over $198,000 designated to the Class of 1922 Professorships.

Regional Solicitation programs were conducted across the country. The keystone of the regional effort was the Personal Solicitation Program, held this year in Atlanta, Denver, Hartford, New York and St. Louis. All in all, 64 volunteers personally solicited 211 alumni, 80% of whom made a gift to the Alumni Fund. Of these, 64% increased their gift amount relative to Fund Year 1986, proving again the effectiveness of face-to-face solicitation. Telethons were held in a total of 17 cities, 7 in the fall and 10 in the spring.

Telethons once again proved their worth as an effective means of personally soliciting large numbers of alumni. Some 967 alumni and student volunteers worked on behalf of the Fund to contact 16,738 alumni, of whom 12,402 (74%) made pledges. A new telethon record was set with $790,496 raised over the course of the year.

The Young Alumni Program continued to foster an awareness and support of MIT among the most recently graduated classes. Some 600 first-time gifts came from the five youngest classes. Forty-four alumni from the four most recently graduated classes gave of their time to serve as Associate Agents, calling from their homes to solicit gifts. As a result of their calls, 113 donors, many of them first-time givers, contributed $3,335. The Class of 1982, on the occasion of its Fifth Reunion from MIT, raised $27,207 as a gift, an excellent showing for a Fifth Reunion class. The Class of 1977 presented a Tenth Reunion Gift in the amount of $77,672, setting an all-time record for a Tenth Reunion class. Nearly $30,000 of this generous gift has been designated to establish the Class of 1977 Student Aid Fund. Finally, the Class of 1972 made the first 15th Reunion Gift in MIT's history, raising $106,480, 42% of which has been designated for the class project, the Class of 1972 Endowed UROP Fund. Over 45% of the class made gifts in Fund Year 1987. These young alumni reunion gift campaigns were one year in duration.

The graduating class of 1987 presented the Institute with funds towards the purchase of Directory Maps, the first of which will be placed on the Student Center side of Massachusetts Avenue. Some 260 seniors contributed a total of $4,965 to the Class of 1987 gift which was generously matched by the 50th Reunion Class of 1937. 287 graduates pledged a total of $29,775 to the Alumni Fund over a four-year period.

The Graduate Alumni Program, temporarily interrupted last year by the search for a new Director, has regained the momentum of the previous year and achieved fine results for fiscal year 1987. Total graduate alumni participation was 31% and 397 first-time gifts were received from those graduated in the five most recent years. Within the relations function of the program, successful programs included a Harbor Cruise for graduating graduate students, the MIT Chemists Club Industrial Laboratory Tour Program and a Space Station Design Lecture Series with alumni speakers invited by Alumni Association President Joseph G. Gavin, Jr., Class of 1941.

During the year the staff was augmented by the following additions: Nelson Armstrong was appointed to the new position of Area Director, Alumni Fund; Jean Blodgett Bruns, following a leave of absence, became the Class Agents Program Director, and Diana Strange was appointed Associate Director of the Fund. There were promotions as well: June P. Coleman to the position of Coordinator of Direct Mail, Laura M. Scarlett as Coordinator for General Gifts Solicitation, Major Reunion Gift Program, and Jeffrey R. Solof was named Assistant Director of the Fund.

Finally it is essential to note that the continuing success of the Fund is attributable directly to the thousands of alumni volunteers who offer their time and energy in support of the Institute. It is they who deserve the greatest accolades for the achievements of this marvelous year.

Technology Review

In a year characterized by turmoil in the marketplace for science and technology magazines TECHNOLOGY REVIEW made modest but important gains in both editorial and business activities. And there is promise that the stage has been set for more significant future gains in both circulation and advertising.
By any standard the highlight of the year was the REVIEW's nomination for a prestigious National Magazine Award in the category of General Excellence—one of the few times in the history of these awards that a university-sponsored publication has been tapped. The REVIEW was also selected by the Council for the Advancement and Support of Education for two gold medals in a "magazine of the decade" competition, one for general excellence and one for writing quality; and there were, as usual, significant awards for the REVIEW's graphic design and illustration from the Art Directors Club of Boston.

The REVIEW continued its editorial emphasis on the implications of technological change—social, environmental, economic, military, international. There is great diversity in both the technologies that underlie change and the nature of the resulting change, and these factors lead to a magazine that is to some readers upsetting, to others diffuse, but apparently to the majority increasingly interesting, even exciting. Among outstanding features in 1986-87 issues were a proposal for post-Challenger space programs by Ruth A. and John S. Lewis; a forecast of the implications of changing military technologies by Frank Barnaby; an evaluation of the space plane by Stephen W. Kortes-Altes, SM '87; Professor Thomas Eager, '72, on the implications of new developments in materials engineering; a pre-publication excerpt from an important new book, Manufacturing Matters: The Myth of the Post-Industrial Economy, by Stephen S. Cohen and John Zysman; a study of managerial and government strategies for keeping traditional industries productive by Professor Charles F. Sabel and three of his graduate students; an essay on how political, legal, and social pressures are limiting the development of new contraceptive technology and the use of existing technology by Elizabeth B. Connell; and a report on the likely future extent and methods for control of the AIDS epidemic by Professor Jeffrey E. Harris.

In addition to her regular editorial work, Alison Bass, Senior Editor, was the author of two important features—an interview on critical issues in biotechnology with Professor David Baltimore and a study of the work of Professor Seymour Papert in bringing computers into young people's education. Ms. Bass' departure at the end of the year to take an editorial assignment at the Boston Globe was a severe loss.

There was only one other change in the staff during the year: Julie Zuckman left us to take a position located closer to her prospective residence in central Massachusetts, to be succeeded as Circulation Director by Beth Rosner. Ms. Zuckman was able to report as she departed in the spring that the REVIEW's performance in the commercial marketplace was improving significantly as the year progressed: the response rate was up at least marginally. Improved editorial performance and better sales strategies are both likely responsible for these encouraging trends.

A third factor may be the REVIEW's fortunate stability in the chaotic market of science/technology magazines. Publication of Science 86 was terminated by the American Association for the Advancement of Science in mid-1986, with the assets acquired by Time, Inc., along with Science Digest magazine, both of which were merged with Discover magazine. Later in the year the National Academies of Science and Engineering announced the termination of Issues magazine. Late in the spring Discover was sold by Time, Inc., and High Technology magazine was sold by Goldhirsh Publishing Co. to Financial News Network, which promised to reorient the magazine to high-technology business interests. After much of its staff had dispersed, Issues was reinstated as the result of special grants to the Academies and will be published as a quarterly for the indefinite future, and it may well represent one of the few significant commercial competitors to TECHNOLOGY REVIEW; another may be The Sciences, published by the New York Academy of Sciences.

The failure of advertising support figured in this turmoil, and TECHNOLOGY REVIEW was not immune. But the prospects for improvement in 1987-88 seem good: the Leadership Network, the advertising cooperative that is our principal source of national advertising, gained considerable strength with the enrollment late in the spring of Foreign Affairs magazine. Peter Gellatly, the REVIEW's Business Manager, has continued as lead publisher for the Network.

Alumni Information Management

Implementation of the Alumni Office automation began with Apple MacIntosh machines used as individual work stations and later being connected to the IBM mainframe.

A joint project with Administrative systems has been the successful completion of the Volunteer Control System.

This year the emphasis on computing has been to stress efficiency. Unused and redundant data fields were deleted from the master file. Using new fourth generation programming tools the transfer of new graduates from the Registrar's Office, was completed three weeks ahead of schedule. The company name field on the database is currently being updated to reflect the Standard & Poor's company name file. The volume of entry to the database increased over last year, but the total number of records decreased to 106,484. A production output scheduling system was designed, written and tested using MIT student help. The system will enable the Association to view all production work for the coming year. Our final major project for the year has been the development of an on-line accounting system. Katherine Cochrane and her staff have been working very closely with IM. Our hope is that this accounting system could be used by the rest of MIT.
Personnel changes during the year involved hiring a new director, John T. Blake in February and promoting Katherine Collupy to a data output position.

Administration

Planning for the renovation of W59 and two other areas of the Alumni Association continued to occupy a large portion of the administrative unit’s efforts during 1986-87. As of early August, it is expected that 24 employees of the Alumni Association will be successfully moved to W59, leaving 10-140 available for renovation for the Alumni Fund. The New York Center is also in the process of moving to new headquarters. By the end of September most of the 74 employees of the Association will be in new locations.

The second most important effort during 1986-87 was that of the development of a totally new financial system for the Alumni Association. At the request of the Audit Committee of the Board of Directors, the Administrative Officer and the Director of Information Management embarked on a project to produce new financial reports for internal and external purposes. The primary focus was to produce these financial reports on a much more timely basis than the Institute accounting system can provide. This will give the managers more accurate information and also provide the necessary flexibility for budgeting and forecasting. This new system is in the process of being implemented and should be fully developed by October 1, 1987.

During this year, the Alumni Association progressed from one level of technology to another at a very quick pace. We now have a fully developed office automation network, using the MacIntosh personal computer as the focal point. Most of the word processors and "dumb terminals" have been replaced by the all-purpose "MAC" and there are plans to further consolidate the existing equipment.

During 1986-87 six administrative staff positions were filled as were nine support staff positions. An additional 12 positions are to be filled during 1987.

WILLIAM J. HECHT