Reports to the President

1984-85

Massachusetts Institute of Technology
Reports for this book were submitted for publications in final, camera-ready form by MIT departments, laboratories, and centers.
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The genius of MIT is that on every hand its people are caught up in the idea of the future. They may be guided by tradition. They may be inspired by history. But they are driven by excitement about the future — what will be, what may be, what can be.

As I remarked in this report a year ago, the spirit of inventing the future was an essential element in the organizing concept of MIT put forth 125 years ago by our founder, William Barton Rogers, a spirit we will celebrate in our quasquicentennial observances early in 1986. It is a source of pride for all connected with MIT that this university and its people have for so long kept faith with that spirit.

By a coincidence of calendar, this annual report is written at about the time students are returning for the start of the fall term. They bring with them all the eagerness, anticipation, and hope of a new generation. And they bring talent. Looking at them, we cannot help but recognize that these are the faces of the future, and that MIT has a pact with that future.

Concern with the future has invested MIT with international stature. We have evidence at every hand that MIT enjoys a position in the first rank of the great research universities of the world. This is true if you consider formal appraisals of the quality of academic institutions or if you rely on reports of a more personal, impressionistic, or anecdotal character. The exceptional stature of this remarkable university is evident to all.

This happy state has developed in the decades since the Second World War — decades that have marked both the beginning of MIT's involvement with sponsored research on a large scale and the remarkable flowering of several key scientific disciplines where MIT people have demonstrated special leadership.

They have been marked, too, by the cardinal influence that MIT people have come to exercise on higher education throughout the nation and the world. It is an influence felt in the shape and substance of curricula, of textbooks, of the educational encounter itself. Many of the educational programs in which we pioneered — such as the project laboratories and the Undergraduate Research Opportunities Program — set standards that are followed at many of our sister colleges and universities. And newer programs, such as Project Athena, hold similar if not greater potential for affecting the ways in which we learn and teach.

Beyond the activities in our own classrooms and laboratories, perhaps MIT's most profound influence on education and research rests with the 4,000 graduates who now serve on the faculties of colleges and universities around the globe.

While institutional leadership such as ours does not submit to easy analysis or to a quick listing of the several qualities on which it critically depends, it is clear that the sine qua non for academic leadership is a faculty comprising individuals who possess uncommon energy, insight, and intellectual capacity, and who share a vision of institutional mission and potential, a vision of the future.

By definition, such faculties can never be static. Faculties that lead are those that are continuously engaged in processes of change and renewal. The same can be said for the scholarly disciplines that underlie MIT's organizational structure. Individuals, acting in pursuit of the challenging ideas and questions of their fields, break new intellectual ground, and in so doing, contribute both to the common store of knowledge and to our capacity to educate our students.

One important element in sustaining faculty leadership may be found in the unending process of renewal that results inevitably from the arrival each year of women and men at the beginnings of their academic careers. These are the agents who bring new and different perspectives to MIT. They enrich the intellectual fabric of the place, whether their stay is of a few years' duration or whether it is permanent. In either case, it is these people who are of critical importance in sustaining MIT's position of leadership in the future.

These faculty colleagues — and our ability to provide the setting and conditions which foster excellence and achievement — hold the key to MIT's future. Let me give substance to these assertions by citing specific examples from the ranks of those who have joined the faculty in recent years.
In the Department of Urban Studies and Planning, Assistant Professor Lynne B. Sagalyn is in the second year of a two-year appointment to a career development professorship endowed by the Class of 1922. Professor Sagalyn, trained in urban economics and planning, has conducted research that has won national attention in an area of keen interest to all Americans -- the cost of buying and the methods of financing housing, particularly for minorities and those of modest means. More recently, she has extended her studies to the analysis of the rejuvenation of downtown areas undertaken with varying combinations of public and private finance. She has found teaching far more stimulating than her original forays into this area as a doctoral student had led her to expect. Her fresh introduction of financial aspects of housing and development into the department's curriculum, together with her spirited teaching manner, have gained special recognition for the department and have attracted students from a variety of disciplines.

Dr. Philip S. Khoury, Associate Professor of History in the Department of Humanities, also a recipient of a Class of 1922 Career Development Professorship, has brought to MIT special distinction for rigorous scholarship in the study and teaching of the political and social histories of the peoples and the nations in the Middle East. His books and articles have earned wide praise, particularly for the new understandings he has been able to present in comparative urban history in the Middle East and in comparative nationalist movements in that region. Students -- and faculty from his own and other departments -- fill his classes on contemporary Middle Eastern affairs, seeking insights gleaned from scholarship and from personal heritage on the tragic and seemingly interminable conflict that rages in that part of the world.

In the Department of Chemical Engineering, where he held the Atlantic Richfield Career Development Professorship until last December, Assistant Professor T. Alan Hatton has proven to be an important asset as teacher, research scientist, and faculty resident in an undergraduate house. Professor and Mrs. Hatton, who live in MacGregor House with their two young sons, regard their interaction with undergraduates as emblematic of what we are all about here. A recipient of the Everett Moore Baker Award for Excellence in Undergraduate Teaching, Professor Hatton takes obvious pleasure in working with undergraduates. He is in charge of a new undergraduate process laboratory, which forms an important part of new educational initiatives underway in his department. His research interests on continuous bioseparation processes relate to assuring an industrial future for genetic engineering. Professor Hatton's laboratory focus is on development of continuous and industrially useful methods of separating out biologically valuable molecules from the heterogeneous media that are the typical products of genetically engineered biotechnology systems. Without efficient methods of separation, many of the promises afforded by genetic engineering and recombinant DNA techniques may not be realizable in an industrial setting.

In the Department of Biology, Assistant Professor Barbara Jean Meyer, a recent recipient of the Whitehead Institute Career Development Assistant Professorship Award, is pursuing an exciting line of research in molecular and developmental biology. Her basic interests focus on trying to understand how genetically derived programs of development are implemented in an organism as a single cell matures into an adult. These interests have been channeled into an investigation of sex determination in nematodes, simple microscopic soil-dwelling worms that exist either as males or as self-fertilizing hermaphrodites.

Professor Meyer's particular concern is the identification of the genetic and biochemical signals that are responsible for transmitting information carried on the sex-determining chromosomes to other genes that are responsible for bringing about either the male mode or the hermaphrodite mode of development. Professor Meyer is attracted to an academic career since it allows her the freedom to pursue basic research unfettered by the requirement of producing marketable items. Like many at MIT, she finds too little time in each day to accomplish all she has set for herself. She is an energetic and effective teacher who takes seriously the need to provide her students with the advice, criticism, and inspiration that mark a good mentor.

The Department of Electrical Engineering and Computer Science is currently one of the bases for a young scientist with an extraordinary range of interests and talents -- Dr. Raphael C. Lee, a surgeon and an electrical engineer. His scientific interests relate to how physical forces in developing skeletal and connective tissues are translated into biochemical events, and, toward that end, he pursues careers in both engineering and medicine. On MIT's side of the Charles River, he is Karl VanTassel Career Development Assistant Professor of Electrical Engineering and Biomedical Engineering and is a faculty member in the Harvard-MIT Division of Health Sciences and Technology. On the other side of the Charles he is Assistant Professor of Plastic Surgery at Harvard Medical School and a member of the surgical staffs at Children's Hospital and Brigham and Women's Hospital.
He also holds appointments at several other Boston area hospitals. In addition to his research, Professor Lee teaches electromagnetic theory and muscle physiology in our EECS department, the anatomy of hand and facial nerves in HST, and supervises a variety of thesis research projects by both undergraduate and graduate students. In 1981 he was selected as one of the first MacArthur Prize Fellows by the John D. and Catherine T. MacArthur Foundation, and earlier this year he was named recipient of a three-year Searle Scholar Award from the Chicago Community Trust.

Associate Professor Randall Davis is now a tenured faculty member in the Sloan School of Management where he is helping to mold the School's innovative programs in management information systems. From 1979 to 1981, when he was a newly appointed assistant professor in the Department of Electrical Engineering and Computer Science, he held an Esther and Harold Edgerton Career Development Professorship. His particular interest focuses on knowledge-based systems, a subfield of artificial intelligence. These systems are computer programs that abstract and systematize the specialized knowledge of recognized experts in a given field, enabling the systems to perform as well as experts, using much the same sort of reasoning. Management scientists look forward eagerly to the development of a variety of knowledge-based systems that will extend markedly the skill and effectiveness of industrial managers employing computer-based information systems. Professor Davis sees this field of research as especially suited to his interest in how people process information, that is, how they understand, reason, and learn.

These brief profiles provide some sense of the stimulating, demanding activities of our faculty. Their interests and talents are far-ranging and compelling. While their fields are disparate, each of these faculty colleagues has one thing in common: significant and timely career development support including, for each of them, a career development chair. This financial support has made a critical difference -- providing not only the freedom and funds to pursue research interests, but also the encouragement and vote of confidence at timely points in their academic careers.

We have an obligation to provide the conditions necessary to stimulate and support this kind of creativity in research and teaching. Salaries are, of course, an important factor in our ability to attract and keep the best teachers and scholars. In terms of basic salary, the Institute is competitive, school by school, with its peer institutions, but we still must ask most of our faculty to raise a portion of their own academic year salaries through research funding. This includes those who are at the beginnings of their careers, and may not yet be well established in their research programs.

At present about 18 percent of our academic-year faculty salaries are charged to sponsored research grants or contracts. (In the Schools of Science and Engineering this fraction is 24 percent.) The practice of charging academic year salaries to sponsored research funds began at MIT in the 1950s; it was one of the ways the Institute leveraged the rapidly growing federal investment in research to increase its size at a time of very strong demand. But there is a cloud over this general practice at present and it holds special portent for newly appointed faculty and for our ability to compete with better endowed institutions.

The practice of paying a part of faculty salaries from research grants and contracts works to the disadvantage of our faculty in the competition for research support. By requiring that research pay a part of the cost of faculty salaries, we put the cost of doing research higher than comparable costs for research performed at those universities, such as the large, publicly supported institutions, which pay all academic-year faculty salaries out of general funds. In any case, MIT's practice places heavy demands upon members of the faculty, including those who are just beginning careers as independent investigators, to generate a steady stream of grants and contracts to support not only the students, technicians, and postdoctoral fellows who are engaged in their research, but also a portion of their own salary and benefits. It strains loyalty to the institution and to undergraduate education.

Basic salary, which is compensation for a faculty member during the September-to-May academic year, is not the only dimension in which we must compete. Research, scholarly activity, and preparation for teaching, particularly the development of new educational materials, continue during the summer. For all, summer is a time when energies can be concentrated, without the regular, repetitive schedule characteristic of the academic year.

We encourage faculty members to be employed by MIT during the summer and to earn additional compensation of up to two months of academic-year basic salary. For most, summer employment is an essential part of their total personal income needs. This tends to be especially true for those just starting careers.
But again, in order to be paid for summer activity, a faculty member must be engaged in activities that have funding available to support summer salaries and benefits. Such activities include teaching in the summer session, working on curriculum development projects, and, primarily, conducting sponsored research. As one might guess, summer support tends to be concentrated in the Schools of Engineering and Science, which have a great many sponsored research programs, and among the more senior faculty. Junior faculty who are not yet experienced in developing research support are much more likely to seek essential summer employment outside of MIT. While they usually pursue outside work that is supportive of personal growth, these individuals are not active members of this community during the summer, and MIT is diminished by their absence.

Beyond salary support, there are other things a flagship institution should do to give newly appointed faculty members the start they need. We should be in a much better position to help new faculty members, particularly those beginning an academic career following graduate or postdoctoral study, begin their research programs. The largest share of the costs of research and scholarly activity will continue to be provided by federal and industrial sponsors, as at present. However, the person striking out for the first time as an independent investigator needs some assistance in developing his or her interests to the point where an outside agency is likely to take an interest in the work. Such start-up funds are usually required to equip a laboratory and to support a graduate student colleague for a year or two. The men and women who are members of the MIT faculty are remarkably effective in generating research support on the basis of the quality, innovativeness, and impact of their work. Nevertheless, new junior colleagues remain greatly in need of institutional assistance in getting started.

For many years we have relied on two endowed research funds for this purpose. The Alfred P. Sloan Fund for Basic Research and the Godfrey L. Cabot Solar Energy Fund together generate just over $2 million per year, which is allocated by a small committee chaired by the Provost. Several of the persons whose profiles appear in the previous section of this report have benefited from these internally generated and controlled seed funds. Important as they are, these funds are limited in two respects. First, the annual income they generate is just 1 percent of the total annual expenditure for sponsored research on this campus; these funds are simply inadequate to the task at hand. Second, they are constrained in their application to work in engineering, the physical sciences, and in nuclear physics. Consequently, important areas of activity, such as the humanities and social sciences, architecture, and management are without institutional sources of seed funds.

Another element of faculty support that relates directly to leadership in academic affairs is our ability to support new educational developments. The development of a new subject, the revision of a departmental course of instruction, or the development of a new text or other form of instruction, all require major investments of thought and energy. They are not activities that are easily undertaken as adjuncts to a normal commitment to teaching and research activities. Such investments in our future as an educational institution are greatly aided by releasing a faculty member from some portion of his or her normal duties for a term or two or by supporting that person during the summer so that time can be spent on educational development. Of course, this requires some source of institutional funds, analogues in many respects to seed funds for research.

Each of these conditions for leadership -- necessary to ensure a position in the first rank of the great research universities -- places demands on the resources of the Institute. They are demands that cannot be met by increasing tuition charges or by expanding the research programs. If we are to respond to these needs regularly and steadily, we must garner substantial additions to the Institute's invested capital base: our endowment. These additions may take many forms:

- **Unrestricted endowment,** the income from which can be used to support any of these needs, but which is essential if we are to continue our efforts to support a much larger fraction of basic academic-year faculty salaries with MIT funds.

- **Endowed professorships,** which provide the holder both with important recognition and with secure funding for salary and for initiatives related to the chairholder's educational or research interests.

- **Endowed funds,** which can be used to seed new research initiatives or to support new educational developments. These funds provide an essential element of institutional flexibility, and their leverage is very great.

Such support is essential if we are to attract and retain new faculty members of the first rank, the individuals who ultimately will sustain into the future this university's leadership in teaching and research.
Perhaps no one understands the need, and the conditions, for institutional renewal more than our much-loved former president and chairman of the Corporation, James R. Killian, Jr. In over six decades of association with this university, he has had an extraordinary influence on the shaping of MIT's character and its devotion to excellence in all things.

This spring, the MIT Press published Dr. Killian's book, The Education of a College President: A Memoir. In a reflective chapter at the end of the book, he gives warmth and depth to this university's unending need for renewal through new generations of faculty:

My hope of progress comes naturally from my having lived so long in the regenerative sanctuary of a research university deeply committed to the pursuit of the first-rate. Along with this circumstance has come the sustained invigoration provided postmeridian by association with a singular fellowship of young men and women working in a contagious atmosphere of excellence, discovery and high spirits.

I look to all within the MIT family -- teachers, students, staff, alumni -- to join together to sustain this "contagious atmosphere." This is our heritage and our future.

PAUL E. GRAY
September 1985
In Special Recognition

Every year there are occasions which remind us of the special character of the many individuals who collectively mold the character of MIT. This past year several key leadership roles at the Institute changed, and those transitions were occasion for special recognition.

In the fall of 1984 Francis E. Low announced his intention to step down as Provost when the 1984-85 academic year ended in order to return to teaching and research. During his tenure as Provost, Professor Low led an Institute-wide academic planning process that will give guidance to the university, its Schools, and its departments in the management and allocation of its resources. In addition, he served as MIT's principal representative in shaping the MIT affiliation with the new Whitehead Institute for Biomedical Research. Above all, Francis Low has consistently displayed a concern for the intellectual vitality of the Institute and for the people who make up the Institute community. As my closest colleague for five years, he brought sound judgment, a balanced and incisive perspective, a gentle humor, and high energy to the affairs of the Institute. In recognition of his leadership, accomplishment and service as scholar, scientist, and administrator, he was named an Institute Professor in the spring of 1985.

John M. Deutch, Arthur C. Cope Professor of Chemistry, who has served as Dean of the School of Science since 1982, was appointed Provost of MIT effective July 1, 1985. Professor Deutch brings to his post a background in a broad range of intellectual fields, wide experience in academic administration, extensive involvement in national science policy, and a dedication to excellence in teaching and research. A member of the MIT faculty since 1970, Professor Deutch is a former Under Secretary of the US Department of Energy. He is a recognized authority in nonequilibrium statistical mechanics, the structure of fluids, dielectric and magnetic relaxation, light scattering and polymer physical chemistry. Professor Deutch's commitment to the mission and values of MIT, together with his enthusiasm for exploring new horizons, will contribute enormously to his effectiveness as Provost of MIT.

Gene M. Brown, Head of the Department of Biology, was appointed Dean of the School of Science effective July 1, 1985. A noted enzymologist, Professor Brown has headed the Department of Biology since 1977.

The special character of MIT is also seen each 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 late winter, the National Academy of Engineering elected six members of the MIT Faculty. New MIT members are: Allan F. Henry, Professor of Nuclear Engineering; Erich P. Ippen, Professor of Electrical Engineering; Ronald M. Latanision, Shell Distinguished Professor of Materials Science; the late Philip M. Morse, Professor of Physics, Emeritus; Claude E. Shannon, Donner Professor of Science and Professor of Electrical Engineering and Mathematics, Emeritus; and Sheila E. Widnall, Professor of Aeronautics and Astronautics.

During the spring, six members of the MIT faculty were also elected to the National Academy of Sciences. Those new MIT members are: B. Clark Burchfiel, Schlumberger Professor of Geology; Mildred S. Dresselhaus, Abby Rockefeller Mauze Professor of Electrical Engineering and Physics; Victor W. Guillemot, Professor of Mathematics; Professor Ippen; K. Barry Sharpless, Professor of Chemistry; and Robert A. Weinberg, Professor of Biology.

Five members of the MIT faculty were among those elected as Fellows of the American Academy of Arts and Sciences at its meeting in May. New MIT members are: David Botstein, Professor of Genetics; Mary Lou Pardue, Professor of Biology; W. Gilbert Strang, Professor of Mathematics; Christopher T. Walsh, Professor of Chemistry and Biology and Uncas and Helen Whitaker Professor in the Whitaker College; and Daniel I.C. Wang, Professor of Chemical and Biochemical Engineering.

In February three members of the faculty were presented the National Medal of Science. Those honored by this recognition are: Bruno B. Rossi, Professor of Physics, Emeritus; Isadore M. Singer, John D. MacArthur Professor of Mathematics; and the late John G. Trump, Professor of Electrical Engineering, Emeritus.

The John D. and Catherine T. MacArthur Foundation awarded a MacArthur Prize Fellowship to Alar Toomre, Professor of Applied Mathematics. Professor Toomre, an applied mathematician and theoretical physicist, was awarded the prize for his work as an astronomer and his work in the dynamics of galaxies.
Within the Institute, Franco Modigliani, Institute Professor and Professor of Economics and Finance in the Sloan School of Management and the Department of Economics, was selected by his colleagues to be the 1985-86 recipient of the James R. Killian, Jr., Faculty Achievement Award. The Killian Award, established in 1971 as a tribute to MIT's 10th president, recognizes extraordinary professional achievements and service. The committee's citation reads, in part, "Franco is an economist of extraordinary professional accomplishments. He is also a colleague of exceptional insight, energy, and enthusiasm. Franco has not been an ivory tower economist. His work is always of central importance for macro policy, and he has taken an active part in policy discussions and debates over the years."

In May, Robert C. Berwick, Assistant Professor of Computer Science and Engineering, was named the 1985 recipient of the Harold E. Edgerton Faculty Achievement Award. The Award recognizes young faculty members for outstanding achievements in research, scholarship, and teaching. A computational linguist, Professor Berwick is developing computational models of language acquisition and processing, drawing on the work of modern linguists in explaining how people acquire language.

Several changes in senior posts in the academic administration were announced this past year. In the spring the Provost-designate, John M. Deutch, announced plans to reorganize the Office of the Provost in order to implement a major new initiative for the improvement of undergraduate education at the Institute. The reorganization includes the appointment of Professor Samuel Jay Keyser, who has served as Head of the Department of Linguistics and Philosophy and Director of the Center for Cognitive Science, to the post of Associate Provost for Educational Programs and Policy. Professor Margaret L. A. MacVicar, Cecil and Ida Green Professor of Education, Professor of Physical Science and Director of the Undergraduate Research Opportunities Program, has been appointed to the newly created post of Dean for Undergraduate Education.

New department or program heads appointed or announced during the past year are: E. Cary Brown, Head, Foreign Languages and Literatures, and Associate Dean of the School of Humanities and Social Science; Richard L. Cartwright, Linguistics and Philosophy; Eugene E. Covert, Aeronautics and Astronautics; Peter A. Diamond, Economics; Maurice S. Fox, Biology; Lowell E. Lindgren, Music; Kenneth R. Manning, Writing Program; and David H. Marks, Civil Engineering.

Other new academic appointments include: David E. Hardt, Director, Laboratory for Manufacturing and Productivity; Jack L. Kerrebrock, Associate Dean of the School of Engineering; Ronald M. Latanision, Director of the Materials Processing Center; Roger G. Mark, Acting Co-Director of the Harvard-MIT Division of Health Sciences and Technology; Phillip A. Sharp, Director of the Center for Cancer Research; Daniel Roos, Director of the Center for Technology, Policy, and Industrial Development; and Richard J. Wurtman, Director of the Clinical Research Center. In the late spring, Mary C. Potter of the Department of Psychology was elected to head the MIT faculty and J. Kim Vandiver of the Department of Ocean Engineering was elected associate chairman of the faculty. Professor Jack P. Ruina will continue as secretary.

Several changes in the Institute's central administration also were announced during the year.

In June, Vincent A. Fulmer, Secretary of the Institute, announced that he would take early retirement after 34 years of service to the Institute. As we noted at the time of his announcement, 34 years is not a true measure of Vince's tenure. It has been 34 years of weekdays, weeknights, and weekends at the Institute, years of foregone vacations and holidays as well. These years have been marked by extraordinary dedication and service to MIT. It is difficult to imagine any single person who could bring the stamina, the knowledge, and the sense of perfection that Vince has brought to this and to every position he has held at the Institute.

Other new administrative appointments include: Michael C. Behnke, Director of Admissions; Laurence H. Bishoff, Executive Director of the Medical Department and Acting Department Head; Michael A. Kane, Acting Medical Director; Helvi McLelland, Executive Director, Council for the Arts; and Shirley M. Picardi, Bursar.

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

Raymond L. Bisplinghoff, Dean of the School of Engineering from 1968-70 and a member of the MIT faculty from 1946-70, died in March 1985. An internationally known aeronautical engineer, he was responsible for the development of research and instruction in flight vehicle structures. Following his years at MIT, he successively was deputy director of the National Science Foundation, chancellor of the University of Missouri-Rolla, and senior vice president for research and development at Tyco Laboratories.
In March 1985, William W. Buechner, Professor Emeritus, died at age 71. He served on the MIT faculty for 36 years and was widely known for his work in nuclear physics. Professor Buechner, a widely known experimental nuclear physicist, helped develop the Van de Graaff generator and played a role in planning for the Bates Linear Accelerator.

Prescott D. Crout, Professor Emeritus of Mathematics, died at age 77 in September 1984. Professor Crout came to MIT in 1925 as a freshman and, except for four years in industry, spent his entire professional life at the Institute. He was highly regarded for his ability to apply mathematics to the solution of complex engineering problems.

In May 1985, Thomas B. Drew, Professor Emeritus in the Department of Chemical Engineering, died at age 83. A pioneer in the use of tensor mathematics in chemical engineering, Professor Drew is a graduate of the MIT Class of 1923 and returned to MIT in 1965 as a professor of Chemical Engineering.

Walter H. Gale, Professor Emeritus, died in July 1984 at the age of 77. A graduate of MIT, Professor Gale was the originator of the Summer Session at MIT and served as the first Secretary of the Institute. He was also a founding member of the MIT Sustaining Fellows.

Jerome H. Holland, who served as member of the MIT Corporation for 10 years, died in January 1985 at the age of 69. Dr. Holland was an educator, civil rights advocate and former United States ambassador to Sweden. He served two consecutive terms on the MIT Corporation from 1969-79.

J. Herbert Hollomon, a member of the MIT faculty from 1972-83 died May 1985. Professor Hollomon, an MIT alumnus, returned to the university in 1970 as a consultant to the president and provost and in 1972 was appointed as the first director of the Center for Policy Alternatives, a position he held until he joined the Boston University faculty in 1983.

In July 1984, Earl B. Millard, Professor Emeritus, died at the age of 96. He came to MIT in 1914 and from 1935-53 was a professor of physical chemistry.

Gwilym A. Price, retired Chairman and President of Westinghouse Electric Corporation and Life Member Emeritus of the MIT Corporation died in June 1985. He was 89 years of age and the eldest member of the Corporation. A lawyer, banker, and industrialist, he was a distinguished leader of industry and a statesman for the business community. In addition, he participated in extraordinary measure in the affairs of the Corporation and the Institute.

Paul Rosenstein-Rodan, whose career at MIT as an economist and faculty member spanned nearly 20 years from 1953-72, died at the age of 83 in May 1985. Dr. Rosenstein-Rodan was one of the early major theorists in development economics, and was credited with coining the term "underdeveloped countries."

In February 1985, John G. Trump, professor emeritus in the Department of Electrical Engineering and Computer Science, died at the age of 77. Dr. Trump was associated with MIT for more than 50 years, serving as a professor of electrical engineering. From the early 1940s until 1980, he directed the MIT High Voltage Research Laboratory, now part of the Laboratory for Electromagnetic and Electronic Systems.

In October 1984, David Floyd Waugh, professor of biophysics in the Department of Biology, died at age 69. He served on the MIT faculty for 43 years and was recognized as an authority on mild proteins, on the chemical and physical processes involved in the coagulation of blood, and on the chemical and physical processes involved in the interaction of protein molecules.

John Wulff, professor emeritus of metallurgy, died in May 1985 at the age of 82. Professor Wulff, who began his career as a physicist, was widely recognized as a metallurgical engineer and known for his contributions to several fields, including surgical bone implants. He was the first holder of the Class of 1922 Chair, a professorship established in 1962 to recognize and support conspicuously effective undergraduate teaching.
Statistics for the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1984-85.

Registration

In 1984-85, student enrollment was 9,626, compared with 9,577 in 1983-84. This total comprised 4,536 undergraduates (compared with 4,602 the previous year), and 5,090 graduate students (compared with 4,975 the previous year). Graduate students who entered MIT last year held degrees from 386 colleges and universities, American and foreign. The international student population was 2,145, representing 13 percent of the undergraduate and 31 percent of the graduate population. These students were citizens of 97 countries.

Degrees awarded by the Institute in 1984-85 included 1,131 bachelor's degrees, 1,045 master's degrees, 56 engineer's degrees, 447 doctoral degrees -- a total of 2,679.

In 1984-85, there were 2,211 women students (1,157 undergraduate and 1,054 graduate) at the Institute, compared with 2,066 (1,090 undergraduate and 976 graduate) in 1983-84. In September 1984, 309 first-year women entered MIT, representing 29 percent of the entering class.

In 1984-85, there were 1,189 minority* students (1,021 undergraduate and 168 graduate) at the Institute, compared with 1,107 (914 undergraduate and 193 graduate) in 1983-84. The first-year class entering in September 1984 included 289 minority students, representing 27 percent of the class.

Student Financial Aid

During the academic year 1984-85, 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 an increase in the amount of MIT loans awarded. Federally guaranteed loans obtained from commercial sources showed a small increase.

A total of 2,461 undergraduates who demonstrated the need for assistance (54 percent of the enrollment) received $14,863,000 in grant aid and $3,085,000 in loans. The total, $17,948,000, represents a 5 percent increase in aid compared with last year.

Grant assistance to undergraduates was provided by $3,953,000 in income from the scholarship endowment, by $2,033,000 in outside gifts and federal allocations to MIT for scholarships, and by $2,399,000 in direct grants from outside sources to needy students. In addition, $5,432,000 in scholarships from MIT's unrestricted funds was provided to undergraduates. The special program of scholarship aid to minority group students represented an additional $118,000 from specially designated funds. An additional 826 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was aided by the addition of $2,275,000 in new funds, which raised the principal of the endowment to $38,389,000.**

Loans totaling $3,085,000 were made to needy undergraduates, a 28 percent increase from last year. Of this amount $736,000 came from the Technology Loan Fund and $2,347,000 from the National Direct Loan Fund. Not included in the foregoing summary is an additional $5,719,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources. This represents a 4 percent decrease in the use of these programs over last year.

Graduate students obtained $1,420,000 from the Technology Loan Fund, $363,000 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, $202,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, $1,822,000, represents a 13 percent decrease from last year's level. Graduate students obtained $3,390,000 from outside sources under the Guaranteed Student Loan Program -- 13 percent above last year's level. The total loaned by MIT to both graduate and undergraduate students was $4,707,000, a 10 percent increase over last year's level.

*Minority students include 315 Blacks (non-Hispanic), 19 Native Americans, 200 Hispanics, and 655 Asian Americans.

**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 accounting records reported by the Comptroller or the Treasurer.
Career Services and Preprofessional Advising

In spite of the slowing of the economy and of a marked pause in the growth of the electronics industry, which has been the destination of large numbers of MIT graduates in recent years, it was a good year for graduates seeking employment. The number of companies and government agencies which came recruiting totaled 431, not much short of 1982's record of 450. (The number compares with 405 in 1982-83 and 407 in 1983-84.) Students, perhaps more confident of their employment prospects, signed up for fewer interviews than the year before -- 9,012, down from 9,896 in 1983-84.

If the change in the economic climate was apparent anywhere it was in the level of salary offers. Offers to seniors in electrical and mechanical engineering were up less than 4 percent; offers to seniors in chemical engineering did not move up at all (with the result that chemical engineering dropped to second place, below electrical engineering, in the ranking of undergraduate majors by salary). The largest salary increases in engineering -- up to 8 percent -- were at the Ph.D. level. The premium paid for a Ph.D. degree in electrical engineering over a bachelor's, which was down to 1.4 five years ago, is back to 1.6 (where it stood in 1974).

One field on which the sun certainly shone, however, was architecture. As many as half a dozen firms came recruiting -- a rare event because most of the time architectural firms count on candidates coming to them -- and salaries were up as much as 10 percent.

For the second year in a row there was an increase in the number of MIT applicants to medical school. They totaled 115, including 81 undergraduates, 10 graduate students, and 24 alumni. (There were 105 applicants in 1983-84 and 101 in 1982-83.) The increase runs counter to a leveling in the number of candidates in the country at large. The final results are not in, but it appears that 88 percent of the undergraduate applicants and 80 percent of the total applicant group were successful. This compares with a national acceptance rate of 48 percent.

Twenty-seven MIT candidates are known to have applied to law school, among them 16 undergraduates.

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 $717,187,000, an increase of 9 percent over 1983-84. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory -- amounted to $299,035,000 during 1984-85, compared with $270,180,000 in 1983-84. The direct expenses of departmental and interdepartmental sponsored research on campus increased from $156,811,000 to $168,311,000; and direct expenses of the Lincoln Laboratory's sponsored research increased from $231,620,000 to $249,841,000.

Current revenues used to meet the Institute's operating expenses totaled $710,345,000, augmented by $6,842,000 in unrestricted revenues. After meeting these expenses, a surplus of $1,512,000 in current unrestricted gifts was held at year-end.

The construction program of the Institute continued to make progress in 1984-85, with book value of educational plant facilities increasing from $298,935,000 to $306,490,000.

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 $679,820,000 and a market value of $920,658,000. This compares to book and market values of $605,378,000 and $771,319,000 last year.

Gifts

Gifts, grants and bequests to MIT from private donors increased significantly in 1984-85 to a new high of $61,714,000, as compared with $49,122,000 in 1983-84. The Alumni Fund reported gifts of $10,128,000 for the year, a new record.

Physical Plant and Campus Environment

The Arts and Media Technology Building was substantially completed by the end of the year. The first occupant, the Committee on the Visual Arts, moved into the building during January and the Albert and Vera List Visual Arts Center was dedicated in March with opening exhibitions of contemporary painting, sculpture, and performance art in the Center's three galleries.
Major renovation projects completed during the year included the Martin Center for Engineering Design on the fourth floor of Building 3, Chemistry research laboratory facilities on the second and third floors of Building 2 (north), and the Center for Real Estate Development on the top floor of the Armory (W31) on Massachusetts Avenue. Athena renovation projects continue to be a major source of design and construction activity, with seven new computation clusters slated for completion during the next year.

The first phase of the campus computer network has been completed. This network has been designed to provide high-speed data communications to as many on-campus computer systems as possible. Gateways connecting the campus computer network to local area networks are located in a number of campus buildings. The major network client, at present, is Project Athena.

In the Housing and Food Services area, substantial changes were implemented in an effort to assure that we continue to meet our goal of providing the best possible services for our students. The Housing operation was reorganized to decentralize much of the immediate decision-making authority and responsibility by moving it to the individual House Managers. House Managers now have the authority to respond quickly to situations that arise, and have the full responsibility for the physical environment, employee resources, and budgeting within their respective Houses.

More than $1 million in renovations and repairs was spent in an ongoing effort to upgrade the housing system. Major structural work took place at East Campus where extensive lintel and brick restoration was performed. New bathroom construction was also completed. At the West Campus houses, a recarpeting program was initiated. A comprehensive program for mechanically updating elevators located in Housing and Food Services department areas was also implemented.

The Food Service operation in the majority of dormitory dining rooms was changed to an a la carte system during the year in response to the students' desire for variety and flexibility. Baker House residents did express a desire to continue its Commons dining program, with some a la carte adjustments to meet their dining objectives, and will be the only House on a Commons dining plan next year.

So that the Faculty Club might better serve its primary function as a center of academic and social exchange, the Advisory Board and management of the Club recommended a full-scale renovation, which began this summer.

During the year, proposals were received for a state-of-the-art digital switching system to replace the Institute's Centrex telephone service as well as the dormitory system called DormLine. Following an exhaustive review of the proposals, an ad hoc committee of faculty and staff working with Telecommunications Systems recommended acceptance of the proposal submitted by AT&T Information Systems. Assuming acceptance of this recommendation by the senior administration, the Institute's Centrex Service and DormLine will be replaced by an Institute-owned PBX in the fall of 1987.

* * *
Personnel Changes

CORPORATION

DEATHS
Gwilym A. Price
Life Member Emeritus

CHANGES OF APPOINTMENT
Norman B. Leventhal
Life Member
Harold J. Muckley
Life Member
John S. Reed
Life Member
J. Kenneth Jamieson
Life Member Emeritus
Laurence S. Rockefeller
Life Member Emeritus
Robert B. Semple
Life Member Emeritus
Richard L. Terrell
Life Member Emeritus

ELECTIONS
Samuel S. Bodman
Member
Joan T. Bok
Member
Colby H. Chandler
Member
Karen L. Fulbright
Member
Michael M. Koerner
Member
Christian J. Matthew
Member
Robert J. Richardson
Member
Robert A. Swanson
Member

MEMBER EX-OFFICIO
E. Milton Bevington
President
Alumni Association

TERMS EXPIRED
Claude W. Brenner
Member
Shirley A. Jackson
Member
Jean Riboud
Member
William J. Weisz
Member
David R. Wilson
Member
Vincent A. Fulmer
Secretary

FACULTY

DEATHS
Thomas B. Drew
Department of Chemical Engineering
Norman Geschwind
Harvard-MIT Division of Health Sciences and Technology
David F. Waugh
Department of Biology

RETIREMENTS
Henry M. Paynter
Department of Mechanical Engineering
Lisa R. Peattie
Urban Studies and Planning
Robert O. Preusser
Department of Architecture
Warren M. Rohsenow
Department of Mechanical Engineering
David J. Rose
Department of Nuclear Engineering
Paul A. Samuelson
Department of Economics
Irwin I. Shapiro
Department of Earth, Atmospheric and Planetary Sciences
Irwin W. Sizer
Consultant in Resource Development

George W. Whitehead
Department of Mathematics

FACULTY RESIGNATIONS

Professors
Alan A. Altshuler
Professor
Department of Political Science
Wesley E. Harris
Professor
Department of Aeronautics and Astronautics
Eric S. Maskin
Professor
Department of Economics

Associate Professor
A. Julia Alissandratos
Associate Professor
Foreign Languages and Literatures Section
Department of Humanities
Michael J. Baum
Associate Professor
Department of Applied Biological Sciences
Max H. Bazerman
Associate Professor
Sloan School of Management

Lennox L. Cowie
Associate Professor
Department of Physics
Paul K. Houpt
Associate Professor
Department of Mechanical Engineering
Ravindran Kannan
Associate Professor
Department of Mathematics
Harry C. Katz
Associate Professor
Sloan School of Management
Timothy J. Kehoe
Associate Professor
Department of Economics
Gary L. Miller
Associate Professor
Department of Mathematics
William T. Thompkins, Jr.
Associate Professor
Department of Aeronautics and Astronautics
Williams S. Widnall  
Associate Professor  
Department of Aeronautics and Astronautics

Michael J. Williams  
Associate Professor  
Department of Linguistics and Philosophy

Clifford Winston  
Associate Professor  
Department of Civil Engineering

Paul C. Xirouchakis  
Associate Professor  
Department of Ocean Engineering

Assistant Professor

Eric A. Barringer  
Assistant Professor  
Department of Materials Science and Engineering

Yohel Camayd-Freixas  
Assistant Professor  
Department of Urban Studies and Planning

Raymond J. Carroll  
Assistant Professor  
Statistics Center

David N. Dobrin  
Assistant Professor  
Writing Program  
Department of Humanities

Joseph V. Farrell  
Assistant Professor  
Department of Economics

Andrew C. Fowler  
Assistant Professor  
Department of Mathematics

Roscoe C. Giles  
Assistant Professor  
Department of Physics

Jeffry N. Kahn  
Assistant Professor  
Department of Mathematics

Barbara S. Nelson  
Assistant Professor  
Office of the Provost

Richard E. Passarelli  
Assistant Professor  
Department of Earth, Atmospheric and Planetary Sciences

H. David Sherman  
Assistant Professor  
Sloan School of Management

Marvin A. Sirbu, Jr.  
Assistant Professor  
Sloan School of Management

Mitra Yip  
Assistant Professor  
Department of Linguistics and Philosophy

PROMOTIONS

To Professor

Mohsen M. Baligh  
Professor  
Department of Civil Engineering

Gabriel R. Bitran  
Professor  
Sloan School of Management

Rafael L. Bras  
Professor  
Department of Civil Engineering

Claude R. Canizares  
Professor  
Department of Physics

Susan E. Carey  
Professor  
Department of Psychology

Edward M. Greitzer  
Professor  
Department of Aeronautics and Astronautics

Alan J. Grodzinsky  
Professor  
Department of Electrical Engineering and Computer Science

John R. Hauser  
Professor  
Sloan School of Management

Berthold K. P. Horn  
Professor  
Department of Electrical Engineering and Computer Science

John G. Kassakian  
Professor  
Department of Electrical Engineering and Computer Science

Paul R. Krugman  
Professor  
Sloan School of Management

Donald R. Lessard  
Professor  
Sloan School of Management

Ole S. Madsen  
Professor  
Department of Civil Engineering

Tomaso A. Poggio  
Professor  
School of Humanities and Social Science

Gerald J. Sussman  
Professor  
Department of Electrical Engineering and Computer Science

William G. Thilly  
Professor  
Department of Applied Biological Sciences

David A. Vogan, Jr.  
Professor  
Department of Mathematics

Alan S. Willsky  
Professor  
Department of Electrical Engineering and Computer Science

To Associate Professor

Lallit Anand  
Associate Professor  
Department of Mechanical Engineering

Amr S. Azzouz  
Associate Professor  
Department of Civil Engineering

Joshua Cohen  
Associate Professor  
Department of Linguistics and Philosophy

Edward F. Crawley  
Associate Professor  
Department of Aeronautics and Astronautics
CHANGES OF APPOINTMENT

Richard B. Adler
Distinguished Professor and
Associate Department Head
Department of Electrical
Engineering and Computer
Science

Jeanne Bamberger
Associate Professor and
Section Head of Music Section
Department of Humanities

E. Cary Brown
Acting Head and Professor of
Economics
Department of Economics

Keiiti Aki
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Suzann T. Buckle
Visiting Associate Professor
Department of Urban Studies
and Planning

Renee A. Fitts
Assistant Professor
Department of Applied
Biological Sciences

William J. Paul
Associate Professor
Literature Section
Department of Humanities

Jose M. F. DeMoura
GenRad Visiting Assistant
Professor
Department of Electrical
Engineering and Computer
Science

Ann F. Friedlaender
Dean of the School of
Humanities and Social Science
and Professor of Economics and
Civil Engineering

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Sloan School of Management

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Engineering and Computer
Science

Thomas M. Stoker
Associate Professor
Sloan School of Management

David K. Gifford
ITT Career Development
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Engineering and Computer
Science

Ka-Kit Tung
Associate Professor
Department of Mathematics

Clark Graham
Professor
Department of Ocean
Engineering

To Assistant Professor

Rosemary Grimshaw
Assistant Professor
Department of Architecture

Rudiger Dornbusch
Ford International Professor
Department of Economics

R. Eric L. Grimson
Assistant Professor
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Engineering and Computer
Science

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Breene M. Kerr Professor
Department of Physics

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Science

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Atlantic Richfield Assistant
Professor
Department of Chemical
Engineering

Richard Adler
Distinguished Professor and
Associate Department Head
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Engineering and Computer
Science

Gian Paolo Beretta
Carl Richard Soderberg
Assistant Professor in Power
Engineering
Department of Mechanical
Engineering

H. Kent Bowen
Director, Manufacturing and
Processing Systems and Ford
Professor of Engineering
Department of Materials
Science and Engineering
Gregory Stephanopoulos  
Professor  
Department of Chemical Engineering

Daniel W. Stroock  
Professor  
Department of Mathematics

Associate Professor

Ronald D. G. McKay  
Associate Professor  
Whitaker College of Health Sciences, Technology, and Management

Walter W. Powell  
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William D. Whidden  
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Associate Professor  
Department of Linguistics and Philosophy

Assistant Professor

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Assistant Professor  
Athletic Department

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Assistant Professor  
Department of Mathematics

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Department of Humanities

Rodney A. Brooks  
Assistant Professor  
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Stephen L. Buchwald  
Assistant Professor  
Department of Chemistry

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Assistant Professor  
Department of Linguistics and Philosophy

Raymond J. Carroll  
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Statistics Center

Yet-Ming Chiang  
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Department of Materials Science and Engineering

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Department of Applied Biological Sciences

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Assistant Professor  
Department of Civil Engineering

Hae-Seung Lee  
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Department of Electrical Engineering and Computer Science

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Sloan School of Management

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Assistant Professor  
Department of Biology

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History Section  
Department of Humanities

Rishiyur S. Nikhil  
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Department of Electrical Engineering and Computer Science

Philip W. Phillips  
Assistant Professor  
Department of Chemistry

Jean-Pierre C. Revol  
Assistant Professor  
Department of Physics

H. Earl Ruley  
Assistant Professor  
Department of Biology

Biswapiya Sanyal  
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Department of Urban Studies and Planning

Robert D. Sproull  
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Department of Chemical Engineering

Theoharis C. Theoharis  
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Literatures Section  
Department of Humanities

Lloyd N. Trefethen  
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Department of Mathematics

Lena Valavani  
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William E. Weihl  
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Department of Electrical Engineering and Computer Science

Jonathan Wylie  
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Anthropology/Archaeology Program  
Department of Humanities

Richard A. Young  
Assistant Professor  
Department of Biology

William R. Young  
Assistant Professor  
Department of Earth, Atmospheric, and Planetary Sciences

David Zeltzer  
Assistant Professor  
Department of Architecture

Adjunct Professor

Lionel C. Kimerling  
Adjunct Professor  
Department of Materials Science and Engineering

Robert H. Pry  
Adjunct Professor  
Department of Materials Science and Engineering

Visiting Professor

Noga M. Alon  
Visiting Assistant Professor  
Department of Mathematics

Eric S. Beckjord  
Visiting Professor  
Department of Nuclear Engineering
Theofilos Cacoullos
Visiting Professor
Statistics Center

Francoise Choay
Visiting Professor
Department of Architecture

Stella C. Dafermos
Visiting Professor
Department of Civil Engineering

Michael G. S. Denny
Visiting Professor
Sloan School of Management

William F. Eddy
Visiting Professor
Statistics Center

William A. Gamson
Visiting Professor
Department of Political Science

Hara P. Ghosh
Visiting Professor
Department of Biology

Dorian M. Goldfeld
Visiting Professor
Department of Mathematics

Jean-Michel Grandmont
Visiting Professor
Department of Economics

Isaac Greber
Visiting Professor
Department of Aeronautics and Astronautics

Curtis Greene
Visiting Professor
Department of Mathematics

Frank H. Hahn
Visiting Professor
Department of Economics

Oliver D. Hart
Visiting Professor
Department of Economics

Gideon Ishai
Visiting Professor
Department of Mechanical Engineering

Lan Jin
Visiting Professor
Department of Electrical Engineering and Computer Science

Bruning Jochen
Visiting Professor
Department of Mathematics

Mitsuru Kurosaka
Visiting Professor
Department of Aeronautics and Astronautics

Francis E. MacGovern
Visiting Professor
Sloan School of Management

Paul G. Malliavin
Visiting Professor
Department of Mathematics

Vincent P. McDonough
Visiting Professor
Naval Science

John G. Moner
Visiting Professor
Department of Biology

Uwe Pape
Visiting Professor
Department of Civil Engineering

Alexander H. G. Rinnooy
Visiting Professor
Sloan School of Management

Herbert E. Robbins
Visiting Professor
Statistics Center

Jagdish S. Rustagi
Visiting Professor
Statistics Center

Louis Sauer
Visiting Professor
Department of Architecture

Martin Schatzoff
Visiting Professor
Department of Mathematics

Emmanuel J. Scivoletto
Visiting Professor and Director
Aerospace Studies

Barry S. Seidel
Visiting Professor
Department of Mechanical Engineering

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Visiting Professor
Statistics Center

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Visiting Professor
Department of Civil Engineering

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Department of Urban Studies and Planning

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Department of Urban Studies and Planning

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Department of Mathematics

Visiting Associate Professor

Adnan Akay
Visiting Associate Professor
Department of Aeronautics and Astronautics

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Sloan School of Management

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Department of Electrical Engineering and Computer Science

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Department of Civil Engineering

Shimshon Frankenthal
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Department of Ocean Engineering

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Sloan School of Management

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Harvard-MIT Division of Health Sciences and Technology
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Tsuyoshi Nakajima  
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Department of Aeronautics and Astronautics

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Department of Mathematics

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Department of Mathematics

Donca Steriade  
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Department of Mathematics

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Department of Chemistry

AWARD

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Institute Professor  
Killian Award  
Lecturer for 1984-1985

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Fiscal Planning and Budget Office

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Systems Planner  
Operations and Systems

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Administrative Staff  
Physical Plant

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Vice President, Resource Development

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Office of the Provost  

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Librarian  
Libraries
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<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Department/Program</th>
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</thead>
<tbody>
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<td>Barbara M. Fienman</td>
<td>Campus Activities Advisor</td>
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<td>Administrative Assistant</td>
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<td>Committee on the Visual Arts</td>
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<td>Charles H. Fuller</td>
<td>Administrative Officer</td>
<td>Writing Program</td>
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<td>Diana V. Garcia-Martinez</td>
<td>Industrial Liaison Officer</td>
<td>Industrial Liaison Program</td>
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<td>Jean F. Gerlach</td>
<td>Technical Documentation Specialist</td>
<td>Administrative Systems</td>
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<td>Assistant Manager, Building Services</td>
<td>Physical Plant</td>
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<td>Assistant Managing Editor, Sloan Management Review Sloan School of Management</td>
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<td>Assistant Director</td>
<td>Admissions Office</td>
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<td>Jeremy Grainger</td>
<td>Bookstore Manager</td>
<td>MIT Press</td>
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<tr>
<td>Jana Heffernan</td>
<td>Archival/Manuscript Specialist</td>
<td>Libraries</td>
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<td>Richard W. Hines</td>
<td>Librarian</td>
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<td>Susan B. Jones</td>
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<td>Richard B. Kaplan</td>
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<td>Literature Section</td>
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<td>Head, Data Base Maintenance Section</td>
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<td>Richard L. Kort</td>
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<td>Jacobo Kredi</td>
<td>Manager, Electrical Services</td>
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<td>Joan Trotter Kyhos</td>
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<td>John F. Lanigan</td>
<td>Analyst Programmer</td>
<td>Office of Facilities</td>
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<td>John J. LaPlume</td>
<td>Engineering Assistant</td>
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<td>Supervisor, Support Services Group</td>
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<td>Carol A. LeClair</td>
<td>Systems Programmer</td>
<td>Operations and Systems</td>
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<td>Susan J. Lee</td>
<td>Industrial Liaison Officer</td>
<td>Industrial Liaison Program</td>
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<tr>
<td>Amira Lefkowitz</td>
<td>Librarian</td>
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<td>Laura J. Letourneau</td>
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<td>Administrative Systems</td>
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<td>David R. LePere</td>
<td>Sales Representative MIT Press</td>
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<td>Grace C. Locke</td>
<td>Administrative Assistant to the Dean</td>
<td>Sloan School of Management</td>
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<td>Kevin E. Lonnie</td>
<td>Industrial Liaison Officer</td>
<td>Industrial Liaison Program</td>
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<td>Debra A. Luchanin</td>
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<td>Lu Lui</td>
<td>Applications Coordinator</td>
<td>Office of Facilities Management Systems</td>
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<td>Richard A. MacMillan</td>
<td>Assistant Director, Council for the Arts at MIT</td>
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<td>Joachim Martillo</td>
<td>Systems Programmer</td>
<td>Project Athena</td>
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<td>James E. Maslow</td>
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<td>Patent, Copyright, and Licensing Office</td>
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<td>John R. Mason</td>
<td>Assistant Budget Officer</td>
<td>Fiscal Planning and Budget Office</td>
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<tr>
<td>Marion McNaught</td>
<td>Space Analyst</td>
<td>Office of Facilities Management Systems</td>
</tr>
<tr>
<td>Name</td>
<td>Title/Position</td>
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<tr>
<td>Ellen Jo McDonald</td>
<td>Assistant Librarian, Libraries</td>
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<td>Meg M. McFaddin</td>
<td>Project Manager, Libraries</td>
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<td>Ann E. McNamara</td>
<td>Journals Editorial and Production Manager, MIT Press</td>
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<td>Sergeant, Campus Police</td>
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<td>Laura B. Mersky</td>
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<td>Elaina M. Myrinx</td>
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<td>Associate Director, Executive Education Programs, Sloan School of Management</td>
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<td>Ronald Newman</td>
<td>Systems Programmer, Project Athena</td>
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<td>Kenneth Nies</td>
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<td>Laxmi Rao</td>
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<tr>
<td>Merrily D. Sterns</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Charles R. Studebaker</td>
<td>Chief Engineer, Central Utilities Plant, Physical Plant</td>
<td></td>
</tr>
</tbody>
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During the academic year 1984-85, the Center for Cognitive Science initiated or continued a variety of programs designed to foster interdisciplinary research in human cognition. These included the development of the Human Subjects Laboratory, a program for visiting scientists and postdoctoral fellows, an affiliates program, a members program, a series of seminars and colloquia, an Occasional Paper publications program, the Lexicon Project Working Papers, and a program of financial support for research initiatives within the Center. Each of these activities is 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.

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, information management, and on-line control of experiments in 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 the Psychology Department each year. In addition, this year undergraduates taking Subject 9.63, "Laboratory in Cognitive Science", used it to carry out their weekly lab assignments.

The Central facility in 20C-231 contains a PDP 11/44 running Berkeley UNIX, two LSI 11/03 minicomputers dedicated to real-time control of experiments, subject testing stations equipped with video monitors, headphones, slide projectors and associated peripherals such as printers, plotters, and tape drives. In addition, the Multi-User Lab maintains two satellite labs in the Psychology Department (E10), each with an LSI 11/03 subject testing station, and hardwired connections to the central computer in Building 20. The main computer can emulate each of the smaller laboratory machines, allowing users to edit and compile their experimental control programs without actually occupying the lab. Programs 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.

This year the first phase of development of the laboratory was completed. Construction of the four subject testing labs and configuring the computers that run them were completed, as was the development of our software for real-time control of experiments. Software for the editing and analysis of speech waveforms will be completed shortly. A high-resolution color graphics monitor has been interfaced to one of the subject-testing stations for experiments on visual processing. Three linguistic databases were installed: the Harvard Child Language Project corpora (this was supported by a grant from the MacArthur Foundation to Carnegie-Mellon University), the Brandeis Verb Lexicon, and a 20,000 word dictionary with pronunciations, part-of-speech categories, and frequencies for each word. Multiplexers and dedicated data lines were installed providing 16 ports for users in the Psychology building. Communications software is being installed, to allow our facility to tie into campus-wide and nation-wide networks.

Research

The Center continued to support two major research projects. The first project, "Knowledge of Language," is under the general direction of Professor James Higginbotham. During the past year this project proceeded through the discussion and planning stage to the production of several essay-length manuscripts by the principal investigators. In addition preliminary drafting of the first of two projected volumes was completed and concrete plans were laid for the integration of the second volume with the first.

The first volume, tentatively entitled Knowledge of Language, will be jointly written by James Higginbotham of MIT, Howard Lasnik of the University of Connecticut, and Edwin Williams of the University of Massachusetts, Amherst. This work will be foundational in character, explaining the structure of syntactic and semantic theory as part of a program in cognitive science designed to illuminate the nature and acquisition of knowledge of language by human beings. It will combine foundational interest with some of the most recent theoretical material within the rough outlines of the Government and Binding theory of syntax. During the fall term of 1984, the authors met with each other and with Noam Chomsky frequently to discuss this material. The second volume is to be made up of individual essays by adjunct investigators.

In May, 1985 the project sponsored a small workshop involving all of the investigators, both principal and adjunct, that were able to attend. The work of the adjunct investigators on detailed differences
among human languages will not only complement the theoretical work, but will also be referred to in that work itself. The growing significance of the lexicon, both for syntactic and semantic theory, was a clear lesson from the work leading up to the workshop and presented there.

The second major research project at the Center is the Lexicon Project. This project, under the supervision of Professors Kenneth Hale and Samuel Jay Keyser, is supported by a grant of $750,000 from the System Development Foundation. This project is concerned with the question of the proper format for a wide variety of languages, including Winnebago, Berber, Warlpiri and English. For the coming academic year Hopi will be added to the list of lexicons under active development. Various dictionary programs are also being developed and implemented to facilitate the use of these lexicons as research tools.

The Visitor Program

During the academic year 1984-85, the Center supported ten postdoctoral fellows: three in psycholinguistics, four in semantics, one in neuropsychology, one in spatial-visual cognition, and one in psycholinguistics and aphasia research. It also hosted three visiting scientists: two in psychology, 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. Currently there are 18 affiliates.

The Member Program

In addition to the affiliate 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: Professors Ned Block, Jerry Fodor and James Higginbotham of the Department of Linguistics and Philosophy, Professors Emilio Bizzi, Jeremy Wolfe, John Hollerbach, and Dr. Neal Cohen of the Department of Psychology, and Professor Judah Schwartz of the School of Engineering.

Seminars and Colloquia

During the 1984-85 academic year the Center continued to support three kinds of seminars. The Center for Cognitive Science Seminar Series, a bi-weekly 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. This year over 500 members of the community attended the seminars. Vision Lunches are weekly lunch-time talks sponsored jointly by the Center for Cognitive Science and the Department of Psychology and held in the conference room of the Psychology Department. Twenty-seven lunch talks were given this 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.

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 32 Occasional Papers have been published. During the 1984-85 academic year seven new Occasional Papers were published.

The Lexicon Project Working Papers

This year the Center sponsored a new series of working papers known as the Lexicon Project Working Papers. 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, two papers have been published: "Lexical Semantics in Review", a volume of reviews edited by Beth Levin of the Center for Cognitive Science at MIT (Lexicon Project Working Papers No. 1), and "The Formation of Adjectival Passives" by Beth Levin and Malka Rappaport of the Department of English at Bar Ilan University in Israel (Lexicon Project Working Papers No. 2).

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 1984-85, a total of four books and 68 articles have been published as a result of Center support and an additional four books are in press.

SAMUEL JAY KEYSER
Center for Materials Research in Archaeology and Ethnology

The 1984-85 academic year was the eighth year of operation for the Center for Materials Research in Archaeology and Ethnology (CMRAE). Activities focused in three areas: graduate education of students from the seven participating universities; doctoral research among students from both Center-affiliated and non-Center universities; and the offering of the fourth month-long Summer Institute course.

The Center was awarded a one-year planning grant by the J. Paul Getty Trust to engage in the design and preparation of a three-year research program with the title Style in Art and Technology: Precolumbian America and Precolonial Africa. The project, which will commence in January 1986, explores the concept of technological style as it is manifest in the art and material culture of societies of Precolumbian America and Precolonial Africa. The Getty grant establishes two postdoctoral fellowship positions at CMRAE which have been awarded to Susan Terry Childs and to Dorothy Hosler, both graduate students at the Center. They will be responsible for guiding the research program during the course of the planning year.

As director of CMRAE, Heather Lechtman represented the United States at the first meeting of a NATO Survey Group on the Scientific Examination and Identification of Artefacts and Works of Art. The meeting, held in Brussels, was attended by representatives from Belgium, Canada, France, and Great Britain. On the recommendations of the Survey Group, the NATO Science Committee will consider the establishment of a new Special Programme in the field of the scientific study of art, archaeological, and ethnographic materials. The Center expects to figure prominently in the development of such a program.

The subject of the Center's year-long graduate offering was Materials in Ancient Societies: Ceramics taught by Professor Suzanne De Atley (MIT, Anthropology/Archaeology). One of its special features was use of a state of the art ceramics furnace designed and built at the Center for fundamental research in the technologies of production of ancient ceramics. Students participated in an important research program, initiated by Professor De Atley, which will provide the archaeological profession with an atlas of microstructures of low-fired ceramic materials studied petrographically and tested at the Center. This experimental program will produce the first set of such reference materials available to archaeologists, geologists, and ceramists.

Six graduate students at the Center, one from the University of California at Santa Barbara, one from MIT, three from Boston University, and one from Brandeis University engaged in full-time research towards the doctoral degree. Of the two students supervised by Professor Lechtman, one is studying the prehistoric development of copper metallurgy in west Mexico and its relation to Andean metallurgies, and the other has begun an investigation into the Precolumbian metallurgy of Ecuador. The four other students are supervised by Professor Suzanne De Atley. Their dissertation research is diverse in scope, including: the ceramic materials fundamental to iron smelting technologies in east Africa during the iron age; standardization and control of ceramic production in the ancient Mexican capital of Teotihuacan; analysis of the ceramic production of Early Neolithic societies of southern France, as they moved from hunting and gathering to primarily agricultural subsistence economies; the technology of Proto-historic pottery in northwest Iberia. All six students carry out their laboratory analyses and experiments in the CMRAE Graduate Laboratory.

The Center established a Summer Institute in 1981-82, conceived as a mechanism through which scholars at non-Center institutions could benefit from the highly specialized and often unavailable education in laboratory-analytical skills in which the Center is expert. The aim is to provide individuals across the nation in such professions as anthropology, archaeology, the histories of science and art, and the conservation of archaeological and art objects with intense exposure to the theory and laboratory methods of the materials science of ancient and art historical materials. The Summer Institute format consists of a one-month intensive lecture and laboratory subject organized around a specific class of materials. The first course, Materials in Ancient Societies: Metals, was offered during June 1982. The second course, Biological Material from Archaeological Sites: Fauna, was funded by a grant from the Alfred P. Sloan Foundation and was offered in June 1983. The June 1984 course, Materials in Ancient Societies: Ceramics, was taught jointly by Professor De Atley and Dr. William C. Nelson, Curator of the Division of Petrology at the Smithsonian Institution, Washington. Funding for the course was supplied in large part by donations from the ceramics industry.
The June 1985 Summer Institute, organized around the subject of Prehistoric Agriculture, was taught jointly by Dr. Frederick Wiseman, principal research scientist at CMRAE, Charla Robinson, a recent graduate of the Computer Aided Design and Geographic Information Systems Laboratory of Louisiana State University, and Christopher Craig, supervisor of the CMRAE Graduate Laboratory. Eleven participants, including 10 graduate students in the fields of archaeology, agronomy, and geology, and one contract archeologist concentrated on two levels of interpretation of land use by societies in the past: the micro-level of analysis, which includes palynology and the identification of plant silica bodies (phytoliths), and the macro-level of analysis, in which the topography of prehistoric land-use patterns can be assessed through remote sensing imagery. The Prehistoric Agriculture course was a departure for the Summer Institute program which, in past years, focused on single classes of materials, such as metals, faunal remains, or ceramics. This issue-oriented approach, involving a variety of materials and laboratory procedures for their examination and interpretation, was an outstanding success and reflects keen interest in and need for the kinds of training the Center uniquely provides.

The Center hosted its first Visiting Scholar, Professor Thomas Longstaff of the Department of Philosophy and Religion at Colby College, Maine, who joined us for the academic year. His appointment was held jointly in CMRAE and in the Program in Science, Technology, and Society (STS).

HEATHER LECHTMAN
MIT Educational Video Productions is the video consulting group for the Institute. Hundreds of faculty, students, and staff come to us for advice on the uses of video in teaching, research, coursework, documentation, artistic creation, and performance. In addition to a great deal of general advice in response to requests for help, our activities fall naturally into three categories. For each of these categories, some examples of individual projects are listed.

1. Requested Videotape Productions. A sampling: VLSI and Biology seminars sent live to Lincoln Laboratories and Harvard University; quarterly reports of Composites Group in Mechanical Engineering to its research sponsor; Lester Thurow commentaries for PBS Nightly Business Report; laser interferometer experiment recorded for Ocean Engineering; Philip Morrison in the Killian Lectures; Morrison and Weisskopf in the Compton Lectures; a project at the Naval Testing Facility in Bethesda, Maryland for the Sea Grant Program; native French children speaking French for a teaching videodisc; System Dynamics Spring Sponsors Meeting, Office of Sponsored Programs.


3. Educational Projects. Examples: Brain dissection tapes, Walle Nauta; student-produced tapes on local French culture; language-interactive videodisc (Annenburg); mechanical design videodisc (Athena); use of facilities by Film/Video classes and Master of Arts in Visual Studies students; physics help sessions on the cable system.

During the past year we moved into facilities in the newly completed and named Wiesner Building. This puts us into proximity with a wide range of high-technology research and development projects that can inform the application of video technologies to the educational tasks of the Institute.

EDWIN F. TAYLOR
Facilities Use

Under the aegis of the Provost's Office, policy for the use of Institute facilities by recognized MIT groups is formulated and implemented. The Administrative Officer in the Office of the Provost is aided in these efforts by a committee whose members this year were Stephen D. Immerman, Director of the Campus Activities Complex; Louis Menand, III, Special Assistant to the Provost; Ronald Suduiko, Special Assistant in the Office of the Chairman of the Corporation; Mary Morrissey, Director of Information Services; Barbara Feinmann, Campus Activities Advisor; Winston E. Flynn, Associate Registrar; Gayle Fitzgerald, Coordinator of Conference Services; and Thomas Murray, Class of 1988 and Facilities Director for the Student Center Committee. The Committee generally meet 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 charted, 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 1984-1985 year, the Institute was host to: National Meeting of the Chi Phi Fraternity; International Conference on Manufacturing, Science and Technology of the Future; Conference of the International Society for Augmentative and Alternative Communication; EDUCOM Conference; Annual Conference of the Society for the History of Technology; Whitehead Institute Dedication Symposium; CALPHAD XIV Conference; Conference on Photovoltaics: Into the Marketplace; and Amnesty International's General Meeting, among others.

CHARLENE M. PLACIDO
Harvard-MIT Division of Health Sciences and Technology

In June 1984 an ad hoc committee to review the Harvard-MIT Division of Health Sciences and Technology was appointed by Presidents Derek C. Bok and Paul E. Gray. This committee was chaired by Dr. Howard W. Johnson, honorary chairman of the MIT Corporation. The members of the committee were Dr. S. James Adelstein, Dean for Academic Programs, Harvard Medical School (ex officio); Dr. Harold Amos, Professor of Microbiology and Molecular Genetics and Chairman of the Division of Medical Sciences, Harvard Medical School; Dr. W. Gerald Austen, Professor of Surgery and Chief of Surgical Services, Massachusetts General Hospital and Harvard Medical School; Dr. H. Franklin Bunn, Professor of Medicine, Harvard Medical School, and Director of Hematology Research, Brigham and Women's Hospital; Dr. Herman N. Eisen, Whitehead Professor of Immunology, MIT; Professor Merton C. Flemings, Head of the Department of Materials Science and Engineering, MIT; Professor Jerome I. Friedman, Head of the Department of Physics, MIT; and Professor Kenneth A. Smith, Associate Provost and Vice President for Research, MIT (ex officio).

The committee met at Endicott House for two and one half days from July 17-19, 1984. It reviewed a two volume report of the HST Division prepared by the Director of the Division and his associates. The committee also heard the testimony of several individuals who had been closely associated with the HST program as it developed; Dr. Robert H. Ebert, former Dean of Harvard Medical School; Professor Walter A. Rosenblith, former Provost of MIT; and Professor Jerome B. Wiesner, former Provost and President of MIT. Dr. Irving M. London, Director of the HST Division; Professor Ernest Cravalho, Associate Director for Medical Engineering and Medical Physics; MIT Provost Francis Low; and Dr. Richard Cohen, Associate Professor of Health Sciences and Technology and graduate of the Program, appeared before the committee, presented their views and responded to questions.

Dr. Howard Johnson had written letters to many individuals who had an association with the Program requesting their opinions, and their responses were made available to the committee during the meeting.

The Presidents of the two universities charged the committee with making a full review of the three principal components of the Division: the Biomedical Sciences Educational Program; the Medical Engineering and Medical Physics Educational Program (MEMP); and the Research Program which involves faculty from both institutions and engages the universities and the Harvard teaching hospitals. The committee was asked for advice on the future of the Division, specifically about possibilities for selective expansion, contraction or termination of each of the three programs.

The review committee agreed unanimously that the record of the Biomedical Sciences Educational Program is uniquely first rate, that it has proven itself, and that it should be continued. They also agreed unanimously that one of the Division's greatest strengths and values lies in the high quality of the students it attracts. The review committee endorsed the concept of the Harvard-MIT collaboration in the education of physicians with a strong background in the quantitative and life sciences and found it fundamentally sound and even more important than ever because of the need for more physician-scientists. It was recognized that the integration of the physical and engineering sciences and the biological sciences into a single curriculum is difficult and generates tension, especially for extremely demanding students. To realize the full potential of this program, the committee recommended that additional principal appointments in the HST Division be made of faculty members whose principal commitment is to the educational and research activities of the HST Division. Such appointments will require additional endowment. The committee also proposed that more uniform requirements for a higher level of skill in the physical sciences, mathematics and engineering be required of students matriculating in the Program. The further suggestion was made that the size of the student body be expanded by three to five students per year i.e. to 28-30, to achieve an integration of the Biomedical Sciences Educational Program and the MEMP Program as described below. The review committee emphasized the requirement that the Program have the explicit support of the Presidents, Provost and Dean of the two institutions.

With regard to the MEMP Program, the review committee proposed that its present form be terminated and that its goals and purposes be pursued in a different manner. They suggested that three to five additional students be accepted into the Biomedical Sciences Educational Program and that these students should be committed to a Ph.D. in Engineering or Physics as well as to the M.D. degree. They proposed further that the interdepartmental Biomedical Engineering Committee of MIT be revitalized and that the Taplin Professor to be appointed at the Massachusetts General Hospital be added as a member of that committee, with the Taplin Professor responsible for organizing rotations for graduate students in suitable clinical departments.

The review committee found that the HST research program plays a fundamental role in fostering collaboration between faculty members in the two universities and that this collaboration in research leads to greater interest in the educational programs of the HST Division. The committee recommended that the research program be enhanced by the appointment of a research advisory council with membership...
selected broadly from the faculties of the two universities, that there should be special emphasis on fostering greater collaboration between the engineering faculty at MIT and the clinical faculty at Harvard, that a regular series of Harvard and MIT research seminars be held to provide further interaction of scientists in the two institutions and that additional funding should be provided to underwrite new ventures and support new efforts.

With regard to the financing of the HST Division, the review committee recommended very strongly that a larger endowment be raised totalling approximately $25 million, that the dependence on annual gifts should be phased out and that both universities should have an equal commitment to the raising of this endowment.

Finally, the review committee noted that there is a special character about the HST Program that especially commends it to the two universities. It remains the principal formal collaboration between Harvard and MIT and it represents a model for interuniversity collaboration.

The strong reaffirmation of the goals and purposes of the HST Division and the laudatory comments of the review committee on the success overall of the HST Program were deeply gratifying to the faculty and students of HST. There was, however, serious objection to the recommendation that the MEMP Program be terminated and melded with the Biomedical Sciences Educational Program. The Joint Faculty Committee and MEMP students urged reconsideration of this recommendation. Since a firm decision on this recommendation was not reached by the end of March 1985, a new class of MEMP students was accepted for admission in September 1985.

Dr. Irving M. London, Director of the HST Division, had indicated in February 1984 that he would retire from the Directorship on June 30, 1985. After several months of deliberation, the Provost and Associate Provost of MIT and the Dean of the Faculty of Medicine and the Dean for Academic Programs of Harvard Medical School decided to appoint two Co-Directors for the HST Division: Dr. Richard J. Kitz, Henry Isaiah Dorr Professor of Anesthesia at Harvard Medical School, and Dr. Roger Mark, Matsushita Associate Professor of Electrical Engineering at MIT.

The performance of HST students continues to be outstanding. Again this year, HST students who constitute only 15 percent of the Harvard Medical School student body received 60 percent of the Honors in a Special Field awarded to students at graduation. MEMP students are also performing superbly. For the second consecutive year a MEMP student was awarded the Young Investigator of the Year Award given by the Biomedical Engineering Society.

HST research programs were reviewed in last year's annual report and will not be considered here. It should be noted however, that a great deal of effort was expended during the past year in the development of a research grant proposal on the therapeutic uses of lasers. Dr. John Parrish of Harvard Medical School and the Massachusetts General Hospital and Professor Michael Feld of MIT took the lead in this effort.

Dr. Walter L. Koltun, Assistant Director for Resource Development, was responsible for raising $531,530, 18 percent more than last year, $105,000 for endowment and $426,530 for expendables including $316,500 for operations and $110,030 for research.

As I retire from the Directorship of HST, I wish to express my deepest gratitude to all those who have contributed to the success of the HST Program and the HST Division. I wish to note particularly the valuable contributions of Professor Ernest Cravalho, Associate Director for Medical Engineering and Medical Physics; Dr. Eleanor Shore, Associate Dean for Academic Programs, Harvard Medical School; Dr. Irving A. Berstein, Assistant Director for Research Program Development; Dr. Walter L. Koltun, Assistant Director for Resource Development; Dr. H. Frederick Bowman, Senior Academic Administrator; Ms. Keiko Oh, Administrative Officer; Miss Virginia Safford, Administrative Assistant, and Ms. Carol Cogliani, Administrative Assistant. Dr. Walter Abelmann, Professor of Medicine, Chairman of the Biomedical Sciences Curriculum Committee and Chairman of the Board of Tutors and Advisors, and Dr. William S. Beck, Professor of Medicine, and Chairman of the Committee on Admissions, have been most important to the growth and development of the HST Program and Division.

I am confident that HST will continue to flourish under the leadership of Dr. Kitz and Professor Mark and that the new Co-Directors will have the full support of HST faculty and students.

IRVING M. LONDON, M.D.
By any of the traditional quantitative and intuitive methods of analysis, the past year was a quite successful one for the Libraries of the Massachusetts Institute of Technology. The level of activity in most areas remained relatively constant, or, as in the case of circulation and cataloguing, showed modest increases. There were the usual number of minor crises but no major ones. What made the past year extraordinary, however, was the fact that, in addition to "business as usual," over half the staff was directly involved in the implementation of automated systems. For a second year, the single most intensive activity in the MIT Libraries was that associated with the impending inauguration of the Geac online circulation system and MARC Records Management System (MRMS). The staff of the MIT Libraries, both those directly involved in Geac and those staffing the operating departments— and those doing both—are to be commended for their exceptional efforts. The past year was clearly one that demanded the very best from a library staff; not unexpectedly, the staff of the MIT Libraries met the challenge in an outstanding manner.

A number of milestones were reached during the year in connection with Geac installation. In April 1985, the Libraries completed the initial MARC monographic records tape load into the MRMS database. A total of 287,847 bibliographic records and 262,763 holdings were loaded, representing monographic items catalogued from 1974 through February, 1985. Since then records are being loaded on a weekly basis. In spite of the complexity of the data being loaded and the strict requirements of the Geac system, the error rate during the load was less than one percent. Call number, author, title, subject, and other number (e.g. ISBN) indices have been created as well.

A barcoding program was run against the MRMS data in June, 1985. The program assigns barcodes to all items in the database and produces a tape that can then be sent to a barcode vendor. In July and August, there will be a major barcoding project using these "smart" barcodes that include library location, call number, author, and truncated title.

New releases were installed during the year: one for the MARC Record Management System in January and one for the circulation system in early July. A new 675Mb disk drive was installed in June that will provide the necessary additional data storage space as the project moves forward. Significant work has been done as well on training and documentation for both the circulation and MRMS systems. Completed are a Circulation Data Entry Manual and MRMS user documentation. A Circulation Functions Manual is near completion. Extensive in-house training of staff on both systems has been underway for some time. MIT has been selected by Geac as a beta test site for the MRMS security program.

A great deal of work has been done in the area of serials. A new Serials Study Team was appointed to study the many serials issues involved in Geac implementation. The MIT Libraries serves as the beta test site for the load and merger of serial records from OCLC and the Faxon Union List system. As a result of this project, some 25,000 serial records will be added to the MIT database, including current holdings for all libraries. The Geac/Faxon Task Force is working on the writing of specifications for the conversion, load, and merger of these records. The prototype system will ultimately serve as a model for a number of other academic libraries that use the two systems for serials.

Responsibility for oversight of the entire Geac project rests with a staff group named the Implementation Coordinating Group. Three study teams (Bibliographic, Circulation, and Serials) were formed and then, under each of these, one or more task forces was assembled. Task Forces currently exist for the following functions and areas: Bibliographic - Holdings, Documentation and Training, Authority Control, and OCLC Archive Tape Processing; Circulation - Patron Database, Training, Finance (fines, replacement charges, etc.), and Document Processing; Serials - Geac/Faxon. In addition, there are task forces on Publicity and Education, Smart Barcoding, and Brief Records. Finally, most of the standing committees in the Libraries (Joint Committee on Technical Processing, Divisional Librarians Group and all of its subgroups; and the Collection Management Group) have been, in one way or another, involved in Geac implementation.

The major goals in automation during the coming year include smart barcoding (July and August); registration of patrons and assignment of patron barcodes (beginning in the fall of 1985); completion of wiring and terminal installation (summer and early fall). The first test site, the Aeronautics and Astronautics Library will be brought online in late summer. The second test site, the Barker Engineering Library will come up some time in the early fall to be followed by other libraries, with full operation expected in early 1986. Public service terminals will be operational in September at all reference desks for consultation and patron access.

There were some other developments connected with the current and future automation of the MIT Libraries. Several discussions took place between the Libraries' administration and the administration of Project Athena regarding the linking of the two networks. The goal is to link users via the Athena network to the Libraries' Geac system, to information about the Libraries and to the assistance and expertise of library staff. While a final decision on funding and scheduling was not made during the year, closure on this issue seems likely early in FY1986. A new
planning group— the Automation Planning Committee— was created during the year. Consisting of the Director, the three Assistant Directors, and the Systems Librarian, this group is charged with long range planning for the application of technology. Among the topics high on its current agenda are Project Athena, an online catalogue, acquisitions, and serials control.

As indicated above, there was no aspect of activity in the MIT Libraries not affected by the extraordinary efforts required in the implementation of the automated system. The remainder of this report will cover some of the highlights in other areas. Detailed summaries of the year's work in each department are contained in their individual reports, copies of which may be consulted in the Office of the Director of Libraries.

Collection Management and Technical Services

Despite pressures on the staff from Geac and from other planning efforts, production in the Cataloguing Department increased during the year. Monographic cataloguing increased by almost six percent and serials cataloguing by over 15 percent. Retrospective conversion was down primarily because of the ending of the two year Title II-C grant in Science, Technology, and Society. Nevertheless, some 5,500 titles were converted during the year. The MIT Libraries submitted an inventory to the Association of Research Libraries of collections of national significance that might be considered for a North-American retrospective conversion project. Subject areas included electrical engineering and computer science, mechanical engineering, architecture, naval architecture and marine engineering, industrial relations, rare books in science and technology, and MIT technical publications. The last named area is the focus of a Title II-C grant that has been funded at $217,500 for a year beginning January 1, 1986 and for which a second year of funding will be requested. MIT also participated for the first time in the National Shelflist Count, a project to gather and publish comparative quantitative data about the size and growth rate of subject collections in research libraries. The inclusion of one of the most important research library collections emphasizing science and engineering seemed especially important and well worth the investment of staff time required.

Evaluation of the New Title Announcement Services (NTAS) continued. A survey of the collections staff regarding the effectiveness of NTAS was conducted through questionnaires and interviews. Re-profiling, in order to improve the usefulness of the program, was carried out in all libraries. A study to determine the comprehensiveness of the program through an analysis of publishers' catalogues will be conducted during the forthcoming year. Perhaps the most important measure of the success of the NTAS plans is that the MIT Libraries appears to have increased the purchasing power of a basically steady-state monographic acquisitions budget by somewhere between eight percent and 10 percent through the additional discounts provided in NTAS plans.

For the first time during the past year, the publication Serials in the MIT Libraries was produced from the Faxon Union List of Serials of the Boston Library Consortium. In addition to the alphabetical title and cross-reference list, a second, KWIC index, was produced. This new index has proven extremely useful to both library staff and patrons. The MIT list, on microfiche, will henceforth appear three times per year following shortly on the appearance of the BLC list.

Public Services

In the divisional and branch libraries, 1984/85 was a year of staff consolidation, a large number of professional vacancies to be filled, and, consequently, a number of staff searches. Regular functions were carried out under pressure from various developmental activities—Geac, Project Athena, the Aga Khan Program, space planning—and from staff shortages in several areas. Regular services were, however, maintained albeit sometimes at a slightly lower level than desired. Efforts continued in planning for the myriad of changes that will accompany the Geac installation and Project Athena.

One of the major events of the year was the coming of age of online quick reference. A level of training and expertise has been achieved that provides a cost effective and efficient use of online information. Online quick reference is now an integral and vital part of reference service. It has improved the image of the libraries and the librarians, saved time, and provided better and quicker information for the user. The replacement of "dumb" terminals with microcomputers has further improved service by reducing the time pressure on searchers and has cut costs substantially.

The microfilm reading equipment in the Chemistry Reading Room, so long in need of replacement, was due for such at the end of the fiscal year. Two new Minolta 505 reader/printers were acquired and all of the film was scheduled to be reloaded into new cartridges. Plans were also developed for the completion of the renovation of the Student Center Library. The remainder of the old duplicate course reserves was scheduled for disposal via a book sale and plans were set for the removal of stacks and enlargement of reading and study facilities.
Administration and Personnel

Several major changes were instituted during the year in the Libraries' performance evaluation system for the librarian and other academic staff. One was to include in the policy statement the following as the primary objective of the system: "To improve the effectiveness of the MIT Libraries in achieving its goals through the continual development of each staff member." The timing of the evaluations was changed to the anniversary date of the staff member's six month evaluation. This has the effect of spreading the evaluations evenly throughout the year rather than having all of them at one time. The form of evaluation, written or oral, will be at the option of the staff member or the supervisor, except that Librarians I will continue to have a written evaluation each year and that every staff member will be required to have a written evaluation at least once every three years. The change here is the provision for a written evaluation at the instigation of the supervisor as well as the staff member. Written performance evaluations will be retained for three years henceforth; previously they were retained for only one year. Finally, under the revised program, the supervisor's part of the written evaluation will include a section requiring the supervisor to state goals and objectives for the staff member for the following year.

In January, 1985, the Libraries issued "Guidelines for the Use of Performance Criteria and Benchmarks" that was designed to be used in conjunction with the annual salary review for librarians and other academic staff and for support staff. It was intended to assist supervisors in arriving at an overall performance statement that can be translated centrally into a percentage increase.


During the January, 1985 Independent Activities Period, the Libraries sponsored or co-sponsored its usual wide range of activities including programs on thesis preparation, New England maritime history, music, MIT history, local writers, office automation, finding a job, Latin America, Boston architecture, needlework, rare books, literature searching, and peace.

Other activities and events of note include the following: the Corporation Visiting Committee met in the fall of 1984; the Libraries conducted a full review of the value of all collections and other property for an update of its insurance policy; the use of microcomputers in all areas continued to grow and a survey of microcomputer use was conducted by the Systems Librarian.

The Library Council retreat took place in May and resulted in the identification of priorities for the coming year. Among the topics receiving the greatest support were, in order of importance: implementation of the Geac Circulation and MRMS systems; increased efforts for fund raising especially for retrospective conversion in-depth planning for an online catalogue; space planning and renovation including the development of a long range space plan for the entire system; expansion of outreach programs to the MIT community including the development and/or renewal of liaison with academic schools and departments; planning for the automation of acquisitions.

Institute Archives and the MIT Museum and Historical Collections

Appraising the Records of Modern Science and Technology: a Guide was published in 1985, culminating three years of work funded by the Andrew W. Mellon and National Science Foundations. The publication represents more than just the successful completion of a project as it makes a critical contribution to the long-range development of the Institute Archives. Faced with the overwhelming bulk of contemporary documentation, archivists recognize the need for informed selection. Appraisal guidelines and collection strategies turn a passive acquisitions program into an informed planned activity. Stimulated by the success of the above project and by the staff's interest in appraisal, the Archives has proposed for outside funding a similar study of college and university records.

Three of the most significant events in the year's work in the MIT Museum were (1) the granting of full accreditation by the American Association of Museums (2) receipt of a general operating grant from the Institute of Museum Services that supported development, reference services, extended hours, and general operations and (3) a major addition of space in Building N51 that permitted the consolidation of the Hart Nautical Collections as well as increased space for exhibitions, staff, and collections. The Board of Advisors met three times during the past year and has formed committees on program and development and on collections.

Grants and Projects

After some five years, the Aga Khan Documentation Project completed its first phase that was the development of a demonstration video disc and images system. The system will be installed at the Rotch Visual Collections, at the Loeb Library of the Harvard Graduate School of Design, and Harvard's Fine Arts Library.
As an outgrowth of the Aga Khan Project, the Libraries through Rotch Visual Collections and in cooperation with the School of Architecture and Planning, has proposed an experiment on the electronic delivery of visual images and text from the library to the academic community. Funding has been received from the Council on Library Resources for support of a research assistant and additional funding has been requested from Project Athena.

The two year Title II-C grant on "Technology and Society" that involved both cataloguing and retrospective conversion of printed materials and processing of archival collections, was completed on December 31, 1984. A new Title II-C project for the cataloguing of materials in the Roman Jakobson Collection on Linguistics commenced on January 1, 1985. This project is part of a two-pronged effort, the other portion of which is a National Endowment on the Humanities funded program for the processing of the Roman Jakobson Manuscript Collection.

The MIT Libraries has received funding from the Title II-C program for the first year of a projected two year project involving MIT technical publications. The grant covers original cataloguing and retrospective conversion of all MIT publications issued between the establishment of the Institute in 1861 and 1974, as well as support for the Institute Archives for processing of several important manuscript collections in the area of science and engineering. The benefits of this project will accrue to both the MIT community by having all the bibliographic information in machine readable form and online through the Geac system and to the scholarly community at large through the OCLC national database.

Space

Considerable time and effort were expended during the year in connection with planning for the expansion of the Rotch Library and Rotch Visual Collections. While a final decision had yet to be made at the end of the fiscal year, there is reason to hope that a satisfactory solution to this long standing problem will be forthcoming shortly. A number of space changes were effected in various libraries to accommodate the needs resulting from the impending installation of Geac equipment. Additional lighting and stacks were approved and, by early summer, were beginning to be installed in the Retrospective Collection building. During 1985/86 there will be a major effort to see what can be done to ease the extreme overcrowding in the Technical Services departments in Hayden Library and also to improve the overall quality of public space throughout the library system.

Gifts

The Libraries continued to benefit from a large number of gifts from members of the Institute community and from those outside. Major collections of printed material were received from James R. Killian, Jr., Salvador Luria, Eli Shapiro, and from the estates of the late Ithiel de Sola Pool and Roman Jakobson. The MIT ROTC Program donated a large number of items from its library that was disbanded during the year. Harfax Database continues to provide a significant number of reference books in the social sciences.

Additions to the Institute Archives were received from a large number of offices with significant additions coming from the Office of the Chairman of the Corporation (James R. Killian), the Energy Laboratory, Office of the Dean of the School of Engineering, Office of the Dean for Student Affairs - Student Assistance Services, Admissions Office, and Information Processing Services.

Manuscript collections were received from Jerome B. Wiesner, the estate of Roman Jakobson, Paul Samuelson, James R. Killian, Jacob P. Ben Harrow, the estate of Ithiel de Sola Pool, and the Union of Concerned Scientists.

Notable additions to the collections of the MIT Museum include a collection of photographs that document the beginnings of early activities at the Frances Bitter Magnet Laboratory; a large collection of video tapes from the Educational Video Resources Group; a collection of instruments documenting MIT's work with human rehabilitation engineering; and a large accumulation of news clippings transferred from the News Office.

JAY K. LUCKER
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 1984-85, LIS offered 37 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications; mechanical, electrical and architectural drafting; printed circuit board design; blueprint reading; machine tools; metal joining; scientific glassblowing; building maintenance; first level management; effective speaking; and computer programming. In addition, refresher courses were offered in mathematics to support both the drafting and electronics curricula. New courses were introduced in alarm technology, housebuilding, electro-mechanical devices, and C, a new computer language.

LIS continued to offer courses in the intensive one-week daytime format for individuals working in industry. A course in real-time control applications of microprocessors was conducted on campus for engineers in local companies.

LIS admitted a total of 1,072 students to its courses in 1984-85. Of those enrolled, 77 percent successfully completed the certificate requirements. Among those who completed courses were 69 MIT employees and three regular MIT students. Fourteen students earned the Certificate in Drafting Technology, and eight students the Certificate in Electronics 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
Again this year, the available resources of the Mining and Mineral Resources Research Institute (MMRRI) of MIT have been utilized to support and encourage new initiatives in teaching and research that are related to minerals resources. Five graduate and five undergraduate students from the Departments of Civil Engineering, Mechanical Engineering, and Materials Science and Engineering have received support from MMRRI funds. Important 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.

A formal agreement has been reached between The Pennsylvania State University and MIT for a joint program for the development of innovative methods in mining and mine systems design. Professor Carl R. Peterson of the Department of Mechanical Engineering has played the primary role in organizing the joint program. The Energy Laboratory and the MMRRI of MIT share in the development of this program. Through the MMRRI, MIT continues its participation in the Generic Minerals Technology Centers for Pyrometallurgy and Respirable Dusts that are sponsored by the Bureau of Mines.

Professor John F. Elliott, Director of the MMRRI of MIT, has been reappointed to the Advisory Board to the Secretary of the Interior on Mineral Resources. Again this year, he received the Distinguished Professor Award from the American Iron and Steel Institute.

JOHN F. ELLIOTT
Since its inception 15 years ago, the MIT Joint Program with the Woods Hole Oceanographic Institution (WHOI) has enjoyed a steady rise in its enrollment. The number of students registered in the Program has increased dramatically over the past three years, giving us an all-time high of 113 students as of September 1984. Projected enrollment for September 1985 is 117 students registered throughout six MIT departments. Of these 117, 24 will be in oceanographic engineering, 19 in biological oceanography, 18 in chemical oceanography, 27 in physical oceanography, and 29 in marine geology and geophysics. Thirteen students graduated from the Program in 1984-85, all with the Ph.D. degree. Of these, there were three physical oceanographers, four biological oceanographers, one marine geologist, one chemical oceanographer, and four oceanographic engineers.

Our 1985-86 applicant pool continued to reflect the downward trend in numbers of applicants to graduate schools nationwide in oceanography over the past three years. The total number of applicants to the Program for 1985-86 was 114, equal to the number of applicants for 1984-85. Of these, 34 were offered admission, 18 of whom accepted. This is an unusually low rate of 52.9 percent acceptance. ONR Fellowships were awarded to two of our incoming students, one of whom also received an NSF Fellowship and the Paul M. Fye Award from WHOI.

The MIT/WHOI Joint Program saw several long-awaited changes during the 1984-85 academic year. The first of these was the move of the MIT Joint Program Coordinator's office, which is now located next to the MIT Director's departmental office. The move has eliminated what was an undesirable distance between the two offices, facilitating communication between the Coordinator and Director. In the future, the Coordinator's office will be located in the department where the Director holds his or her faculty appointment.

A major development for the Joint Program in 1984-85 was the establishment of a microwave link between MIT and WHOI. The hardware for the link has been erected atop the Green Building at MIT and the Clark Laboratory at WHOI, with Monk's Hill in Kingston, MA as the relay between the two sites. The first tests on the equipment will be conducted in late July 1985, and the link itself should be operable in the fall of 1985. The microwave link ultimately will improve communication and reduce commuting between the two institutions by enabling students, faculty, and staff to participate "live" in classes, seminars, and meetings. The next stage of development will be for high speed data transmission between the two institutions.

An especially significant development for the Program this past year was reaffirmation by the WHOI Trustees of a joint S.M. degree between the two institutions. (The MIT/WHOI Joint Program currently offers only doctoral and engineers degrees.) MIT approval is pending until the fall of 1985, when the proposal for a joint master's degree will be presented to the Committee on Graduate School Policy, the MIT faculty, and the MIT Corporation.
The Northeast Radio Observatory Corporation (NEROC) is a consortium of 12 institutions* formed in 1967 to promote radio and radar astronomy research and facilities in the northeastern United States. NEROC receives financial support for its principal facility, MIT's Haystack Observatory, from the National Science Foundation (NSF) for radio astronomy observations. The Observatory also receives project support from the National Aeronautics and Space Administration (NASA), the National Geodetic Survey (NGS), and the National Radio Astronomy Observatory (NRAO). By agreement, NEROC uses the administrative services of MIT in the conduct of its business. Observing proposals submitted by prospective users are considered by a review committee on the basis of scientific merit and suitability of the available instrumentation.

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 18-, 13-, 6-, 3.5-, 2.8-, 1.9-, 1.3-, and 0.7-cm wavelength. The Haystack telescope constitutes an important astronomical resource, particularly in the wavelength region 1.3-0.7 cm, which lies between the shortest wavelengths covered by most of the larger telescopes and the longest wavelengths at which the smaller, true millimeter-wave instruments are most profitably used. At 0.7 cm, the telescope has a beamwidth smaller than the 1-arc-minute resolution of the human eye.

In the past year, the telescope was used by approximately 80 investigators from over 30 different institutions, and 40 articles were published in scientific journals based upon this work. Approximately 10 percent of the telescope usage was by MIT faculty and their students.

A major highlight of the past year has been the refurbishing and upgrading of the 150-ft radome that houses the Haystack antenna. During 1984, 235 of the eroded panels were replaced with a thinner, more durable material called ESSCOLUM-IV (TM). This task will be completed in the summer of 1985 with a net replacement of 835 out of 930 total panels, as well as certain corroded hardware in the space frame structure. In addition to providing an improved shelter for the antenna, major benefits will accrue in sensitivity at wavelengths below 1 cm due to the thinner panels, and observations will improve following rainstorms due to the faster drying time of the radome. Some evidence of improved performance has already been obtained.

A new maser amplifier receiver with about 200K system temperature operating in the broad frequency range 36-46 GHz (0.7 cm wavelength) was installed on the antenna during 1984. It has been used to detect silicon sulphide at 36 GHz in circumstellar gas clouds and HNCO at 44 GHz in Sagittarius A, and to study the v=0, J=1-0 transition of SiO at 43 GHz in regions of young star formation. An improved version of this maser was installed in early 1985. System temperatures from 120K to 240K were observed to be a function of the operating frequency due to the proximity of the atmospheric oxygen absorption line. Key observations have recently been made with this new maser of the CS line in several radio sources that indicated the presence of high density gas. Haystack possesses a unique measurement sensitivity at this frequency amongst U. S. radio observatories and anticipates strong demand from the astronomy community for observations of this line in galactic and extragalactic regions.

Highlights of single antenna astronomy research in the past year in the 20-25 GHz band (1.3 cm) included the discovery of the most luminous H_2O maser source yet detected. This maser source, having a luminosity of ~500 L_0 is located in the nucleus of the distant galaxy NGC 3079, which is also a bright infrared source. In addition, regions of star formations and high velocity mass outflow in our galaxy were studied using the inversion transitions of the NH molecule. These transitions which are closely spaced in frequency and detectable using Haystack’s high resolution digital correlation spectrometer, require

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*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, University of Massachusetts, University of New Hampshire, and Yale University.
widely differing conditions for excitation and allow molecular cloud parameters such as temperature and density, as well as dynamical information, to be obtained. Very high velocity gas was detected in the galactic center using the NH$_3$ molecule. This gas is thought to be stripped from the nearby molecular cloud and falling into the galactic center.

Very Long Baseline Interferometry (VLBI) research continued to be a major activity at Haystack. In this technique signals recorded from the same object simultaneously by several radio telescopes are brought together at a multi-station correlator to yield interferometer fringes. For studies of radio source structure or astrometry, VLBI attains resolution superior to that offered by any other radio or optical method. Haystack is a keystone antenna in the U. S. VLBI Network and provides coordination of the Network in the form of its Scheduler/Manager, currently a Haystack staff member. The U. S. Network and its counterpart in Europe use the radio sources and employ the Haystack MkIII Processor for correlating the interferometer tapes. In the first five months of 1985, nineteen astronomical programs utilized the Haystack correlator.

There are several notable accomplishments among these astronomical programs. The galactic X-ray source Cygnus X-3 fortuitously exhibited an unusually strong radio outburst during VLBI observations; as a result it was possible to measure the expansion of the radio flare as it progressed. Observations of radio-bright binary star systems in our galaxy have now followed the evolving structure of their radio emission. The results of VLBI studies of the compact radio source at the center of our Galaxy garnered considerable attention in both the popular and professional media.

Improved resolution in VLBI measurements can be obtained by using a longer baseline or by observing at a higher frequency. Since global baselines are routinely used at frequencies up to 22 GHz, the current effort is toward increased baseline lengths at higher frequencies. Recent observations at 89 GHz on California to Massachusetts baselines, made with the MkIII system, have given a resolution of 1 nanoradian for several extragalactic radio sources.

New mapping techniques for the VLBI observations have been developed at Haystack which allow the structure of much weaker objects to be determined. The recent addition of a new computer system will give Haystack Observatory an image processing capability which is necessary to analyze the observations. This will allow the Haystack scientists as well as guest investigators to perform complete processing of VLBI data at one location.

VLBI also provides the necessary accuracy to do geodetic measurements of geophysical interest. With support from the NASA Crustal Dynamics Program, Haystack and other observatories, such as that at Onsala, Sweden, are used to measure the relative movement of major tectonic plate systems on the surface of the Earth. Preliminary results from MkIII processing show that the distance between Massachusetts and Sweden is increasing at the rate of about 1.7±1 cm per year. A study of regional deformation along the Alaska-Pacific plate boundary was begun with successful measurement in the summer of 1984 of the distances between about ten sites in Alaska, Canada, and the United States. In the same period, first measurements were made from Alaska and the United States to Kwajalein Atoll, Japan, and Hawaii. These will be repeated each year for the next several years to look for changes that are expected from geological history or that may presage the violent earthquakes that are known to occur along the major faults surrounding the Pacific basin. For example, in the Western United States, where regional deformation studies have been underway for several years with particular emphasis on the San Andreas Fault region of Southern California, the data accumulated since 1980 using the MkIII system shows a contraction of 6±2 cm per year between northern and southern California, consistent with that expected from other types of observation.

A major step forward was begun with the approval by Congress to proceed on development of the Very Long Baseline Array (VLBA). The VLBA, to be constructed under NSF sponsorship, consists of a 10-element VLBI array of 25 meter telescopes covering the continental USA, Hawaii, and Puerto Rico. Haystack staff will be responsible for the development of the data acquisition and playback systems of the VLBA; this includes design and construction of a prototype of the digitization and high density recording sub-systems. The VLBA, which will be 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.
Of great importance to both the current and future VLBI programs, including the VLBA, has been the development by Haystack engineers of a high density recording system which will provide a factor of 12 reduction in the number of tapes required for VLBI experiments. During the past year the techniques and equipment necessary for production of large numbers of these systems have been developed. It is expected that most major radio observatories will be equipped with the density upgrade by the end of 1986. Coupled with an on-going enhancement in MkIII correlator speed and capacity which should also be completed next year, the two developments will provide a significant increase in the amount of astronomic and geodetic information obtained by VLBI.

The 60-foot diameter Westford antenna, located one mile south of the 120-foot telescope, was operated as a dedicated geodetic VLBI station for the NGS and for NASA. The primary goal of this project, now renamed IRIS (International Radio Interferometric Surveying) in recognition of its international character, is to measure the earth's rotation. Absolute determination of the rotation rate or length of day (UT1) and of the point of intersection of the earth's axis and the crust (polar motion) is made at intervals of five days by observing for 24 hours continuously. Other regularly participating antennas are located in Ft. Davis (TX), Richmond (FL), Wettzell (Germany), and Onsala (Sweden). Over 250 separate observing sessions have been held to date. The data are compared to those obtained by optical and satellite-tracking methods in the international MERIT campaign of intercomparison of techniques. The IRIS measurement RMS accuracy is about 0.1 msec in UT1 and 10 cm in polar motion, and is the most accurate and reliable technique for measuring these quantities. An experimental series of daily, quick determinations of UT1 also yielded accuracy of 0.1 msec in UT1 and has become a regular feature of the program. A very close correlation between estimates of atmospheric angular momentum and UT1 has been observed. Present observations are focused on watching for transient anomalies in UT1 which may occur with crustal adjustments associated with large earthquakes. All these measurements are of practical importance in timekeeping, surveying, and navigation as well as being of fundamental interest to earth science.

The installation of a low-noise, cryogenically cooled receiver at Westford in Spring 1985 has not only improved the accuracy of the IRIS observations, but also made possible a shift of most of the geodetic observing load from the 120-foot to the 60-foot antenna. Other cryogenic receivers now being built at Haystack for Ft. Davis, Wettzell, and Onsala, will further increase the sensitivity and accuracy of these measurements.

JOSEPH E. SALAH
The purpose of this report is to summarize the activities of the Office of Minority Education (OME) during the 1984-1985 academic year. OME has continued to implement programs and activities, described below, in order to supplement MIT's ordinary educational resources in a manner that provides minority students here an increased opportunity to successfully complete their undergraduate education. Thus, the Office provided a range of academic support programs with the aim of giving students, who come from groups under-represented by their numbers at MIT (Native-American, Blacks, Mexican-Americans, and Puerto Ricans), alternative sources of access to become engaged in the educational processes of the Institute. During the 1984-85 academic year, following the departure of Dr. William McLaurin at its inception, the role of Director of OME was filled on an interim basis. During the first academic semester, Frank E. Perkins served as the Acting Director of OME while continuing to function in the role of Associate Provost and Dean of the Graduate School. For the second academic term, Sylvester J. Gates, Jr. filled the position while discharging responsibilities as Assistant Professor in the Department of Mathematics. As she has done since 1979, Ms. Pearlline D. Miller served as Assistant Director of OME throughout this period. Through the past year Ms. Gloria E. Payne served most capably as the Office Manager and undertook additional responsibilities as dictated by circumstances.

The Office has provided a center for minority student activity and informed support to these students. The role of office secretary was also filled on a short term basis. Once again this was due to departure of some personnel, specifically Ms. Mireille Desrosiers. However, Ms. Carol Hood began to serve as office secretary at the beginning of the second semester and capably filled that role throughout the term. Additionally, the Office profitted from the services of several student staff members.

An OME "Open House" was held on September 6, 1984. An informal dinner/discussion meeting was held in the Mezzanine Lounge of the Student Center on November 26, 1984. Undergraduate and graduate minority students were invited to share their views regarding current OME academic support programs as well as to provide suggestions for additional support structures that could be explored.

ADVISORY STRUCTURE

OME received the counsel of students and some faculty and staff members throughout the Institute. The Student Advisory Group gave input to the Office regarding student concerns and existing programs. The faculty-staff advisory committee which normally functioned in an advisory role should resume its function in the coming academic year.

Since the present Acting Director will depart effective August 31, 1985, a Search Committee has existed and functioned since February of this year. This committee, chaired by Professor Phillip Clay, Department of Urban Studies and Planning, is nearing completion of its charge and a new Director should be appointed by the end of July.

PROJECT INTERPHASE

The PROJECT INTERPHASE program of 1984 represented the fifteenth year of its existence as a program for minority MIT freshmen. Dr. William McLaurin was in charge of the overall philosophy and direction of the program and supervised its academic content. There were 47 student participants in PROJECT INTERPHASE 1984.

Note: A fifteen-page survey questionnaire was distributed in the fall term to seek students' impressions of the impact of PROJECT INTERPHASE 1984 on their MIT experiences, and to help the Office plan for PROJECT INTERPHASE 1985, as well as to plan for more effective academic support structures for minority undergraduates.

At the time of this report, OME is operating PROJECT INTERPHASE 1985. Professor Alan Davison of the Department of Chemistry is serving as the program's academic officer. Forty minority students are participating in the program.

MINORITY INTRODUCTION TO ENGINEERING AND SCIENCE (MITES)

OME for the second year was responsible for the implementation of the MITES program. There were 56 high school student participants selected from a nationwide applicant pool. The purpose of the program was
to provide an intensive academic experience in science and engineering to the students.

There were a number of programatic and academic changes. The program was lengthened from three to six weeks, a course in biochemistry and life science laboratory were added, seminars to encourage students’ motivation, career interests in electrical, mechanical engineering, mathematics and medicine were offered. A corporate fellowship program which established contact between program participants and funding corporations was also added.

At the time of this report, the MITES program is also in operation. However, the actual administration and operation of MITES 1985 is being carried out through the offices of Professor Ernest Cravalho of the Department of Mechanical Engineering.

**BLACK STUDENT UNION TUTORIAL PROGRAM**

The Black Student Union (BSU) Tutorial Program continued to provide tutorial assistance to undergraduate students. The student coordinators during the Fall term were Xavier Kevin Marshall, D'Juanna White, and Elliott Williams. Mr. Williams resigned his position at the end of the fall semester. The tutorial program is staffed by graduate and undergraduate tutors as well as program secretaries. In 1984-85 the program provided over 3500 hours of tutoring in more than 60 subjects. To introduce the services of the program to students, an opening dinner was held in Burton Dining Hall. All minority undergraduates within the charge of OME as well as minority graduate students were invited.

The Freshman Buddy System continued to operate as a part of the BSU Tutorial Program. The System provides academic and non-academic support to freshmen the purpose of which is to foster a sense of community and to act as a positive influence to the 'buddies.' During the fall term the student coordinators were Gerald Baron and Linda Stephens. Mr. Baron resigned his position at the end of the fall term. There were 70 upperclass 'buddies' assigned to 106 freshmen during the fall term. Upper-class buddies were usually paid for their services. This practice was stopped during the 1984-85 academic year. It is expected that future upperclass buddies will 'volunteer' their services to continue to encourage communication and to foster friendship between buddies. There were two study breaks as well as one basketball game organized by the coordinators.

**FRESHMEN WATCH**

With the cooperation of the faculty and staff teaching science requirement subjects, freshmen have been asked, as needed, to come to OME for academic counseling and tutorial service. This program supplements the activities of the Freshman Advisor and communication with each advisor is maintained. There was a total of 69 students contacted during the academic year 1984-85.

**STRATEGIES AND SECRETS FOR ACADEMIC SUCCESS (SSAS)**

The focus of this activity is to introduce students to the academic and non-academic resources within the MIT community which can serve to promote an effective undergraduate experience, provide valuable contacts and resources as well as explore post-baccalaureate and professional pathways.

The Fall 1984 SSAS coordinators were Charles Coleman, Kyla Thomas, and Chiquita White. At the end of the fall term, Ms. Thomas and Mr. Coleman resigned their positions. Ms. Tara Adams and Mr. Robert Satcher were hired to replace them. There were usually four SSAS seminars per semester. Historically, the primary focus of the seminars were to address the needs and concerns of freshmen. However, efforts have been made to plan more sessions of interest to upperclass students. On the average, approximately 30-35 students attended each session.

**INDEPENDENT ACTIVITIES PERIOD (IAP)**

There were four seminars held during IAP 1985. Three of the seminars focused on aspects of mathematics and physics: (1) Living with Vectors, (2) A Statistical Approach to Thermodynamics, (3) The World of Partial Differential Equations (PDE). An MCAT Review Session provided an intensive review of the sciences covered on the MCAT exam as well as test-taking techniques. This seminar is particularly useful to students applying to medical schools.

**AWARDS AND GIFTS**

This year the Office of Minority Education received a grant of $2000 from the Minority Engineers Development Program of the Hercules Corporation.
Robert Satcher, a junior in Chemical Engineering, received the Monsanto Achievement award. The award consists of a plaque and a $500 award given by the Monsanto Company to a black junior student in engineering who has the best academic record. The award is provided "to promote academic excellence among minority engineering students at MIT."

SYLVESTER JAMES GATES, JR.
Operations Research Center

The Operations Research Center (ORC) was established in 1953 to provide educational and research opportunities for students and faculty interested in the interdisciplinary field of operations research. The academic staff of the ORC is drawn from many departments, including the Sloan School of Management, Electrical Engineering and Computer Science, Urban Studies and Planning, Aeronautics and Astronautics, Civil Engineering, Mechanical Engineering, Ocean Engineering, Mathematics, and Physics. The ORC is managed by two codirectors, Professors Richard C. Larson and Jeremy F. Shapiro, and a core of administrative staff. Approximately 40 graduate students were enrolled in the master's and doctoral degree programs, and 20 faculty and a number of visiting scientists were affiliated with the Center during 1984-85.

Faculty and students at the ORC were engaged in a broad range of activities during the past year. Research was directed at numerous topics in applied industrial operations research, network optimization, public sector applications, energy planning, transportation and logistics planning, applied queueing research, mathematical programming, and computer graphics modeling. In this report, we discuss briefly each of these areas and highlight the Center's educational activities.

RESEARCH ACTIVITIES

Mathematical Programming

Mathematical programming is the field concerned with methods for creating and solving constrained optimization problems. ORC faculty and students made theoretical contributions to the field in several areas.

Under National Science Foundation funding, research continued on network design and facilities location models. New results were obtained characterizing the polyhedral structure of linear programs associated with these models. The research has also led to optimization-based heuristics, derived from mathematical programming duality, that allow very large models to be solved efficiently. Analysis was completed on the asymptotic probabilistic analysis of Euclidean location problems, thereby providing game theoretic bounds on the optimal objective function value and heuristics guaranteeing "good" probabilistic performance.

Several new results were obtained for the network reliability problem which, in its standard form, consists in evaluating the probability that a given graph remains connected, while its nodes and arcs are being erased independently. Reliability design models were developed for analyzing failure dependency in capacitated and spatially distributed networks.

Research originally funded by the National Science Foundation continued on the application of group theoretic and Lagrangean techniques to mixed integer programming models. New procedures were identified for combining the techniques with branch and bound, decomposition and surrogate constraint methods. New algorithmic approaches to mixed integer programming based on these techniques have been implemented, and experimental testing is underway.

Research progress was made in several other areas of mathematical programming. New results were obtained characterizing the sensitivity of a linear program to simultaneous changes in its matrix coefficients. The computational complexity of set containment problems involving convex polyhedra was investigated and shown to be NP-complete. Further research was performed on the optimization of dynamic periodic systems, with applications to transportation, work force scheduling, and inventory control. This last work was supported by the National Science Foundation.

Transportation and Logistics Planning

Research continued on the application of operations research models and methods to transportation and logistics planning problems. Under a grant from the United Parcel Service, research was conducted on optimization approaches for routing and consolidating large-scale point-to-point delivery systems. Similar research was performed on algorithms for concave-cost less-than-truckload consolidation problems.

Research was completed on a project sponsored by the Office of Naval Research concerned with mathematical programming research on complex scheduling problems. These are problems associated with naval "emergency scheduling problems," such as those arising when a large number of ships must be moved from one area to another in a prespecified time window. The research has produced new solution methods for solving these emergency scheduling problems, including interactive heuristic procedures and hierarchical decomposition techniques.
Operations research models were developed for examining the choices made by firms in designing their logistics systems. In particular, the research focused on how the nature of cost-service trade-offs in their industry affect the firm's logistics system design choices. Finally, research was begun on a nested decomposition approach to vehicle routing and scheduling problems. This approach exploits Lagrangian duality for the traveling salesman problem in the construction of a resource-directed decomposition algorithm.

**Applied Industrial Operations Research**

ORC faculty and students were involved in several research efforts aimed at improving the design and control of manufacturing systems. In one project, a family of decision models was developed for supporting Materials Requirements Planning in multi-stage production environments. These models capture the complex interactions among decisions regarding production, capacity, inventory, and order completion, thereby allowing the production manager to identify optimal or at least good short-term master schedules and capacity loadings. New decomposition methods exploiting special structures have been constructed for optimizing the models. This research, supported in part by Draper Laboratories, is entering the implementation and validation stage.

Similar modeling research in production/inventory planning and control was performed for an integrated-circuit manufacturing facility and for a discrete-parts batch manufacturing operation. A new optimization model was developed for the Kanban system in a multi-stage capacitated assembly-tree-structure production environment. Research also began on optimization models for designing and controlling flexible manufacturing systems.

Research continued into new descriptive and normative planning methods for rapidly changing manufacturing environments. Quality-based learning models were derived for analyzing the cost tradeoffs inherent in choosing quality levels, as well as the cost decreases due to volume-based experience. Capacity expansion planning models, based on mathematical programming, that explicitly capture the relationships between capital investments and learning, have also been constructed and validated.

Operations research model building activities continued in several areas of marketing. New models of customer behavior and market response were constructed and calibrated using data collected by optical scanners at the point of purchase. At the core of this work is a multinomial logit model of customer choice among brands, with price, promotion, brand loyalty, and package size being principal explanatory variables. Research continued on consumer models for analyzing the problem of how firms can, do, and should defend their products from new product entries.

ORC faculty and staff were involved in several projects where large-scale mathematical programming models were successfully applied to important business planning problems by imbedding them in user-friendly decision support systems. At IBM, a system that employs mixed integer programming was implemented for selecting vendor contracts. The system is now in active use by buyers at several manufacturing locations. A system for allocating forecasted sales to plants was developed for a chemical company. The mixed integer programming models used by this system integrate manufacturing and distribution plans in determining a strategy for minimizing the total cost of delivering the company's products of the markets.

Research and testing began on new methodologies for generating and optimizing operations research models on microprocessors. A spreadsheet optimization system was designed and implemented which effectively links electronic spreadsheet programs to linear programming models and optimization routines. The user develops the data for a model using an electronic spreadsheet. He/she indicates that certain cells in the spreadsheet are unknowns or variables. A model generation program reads the spreadsheet and creates the linear program implied by the indicated variables; constraints are written on spreadsheet formula involving these variables. The linear program is then optimized, and the optimal solution is returned to the user in the same spreadsheet format in which the model was originally specified. This technology was applied to logistics planning in a consumers' products company, annual planning in a small manufacturing company, and fixed income portfolio analysis.

This year, research was completed on a new class of inventory distribution problems. In this type of problem, a central depot assumes responsibility for replenishing probabilistically depleting inventories of customers who are spatially distributed throughout a service region. The problem formulation and solution utilizes up-to-the-minute inventory state information to adaptively route and schedule replenishment vehicles in order to minimize the sum of transportation cost and inventory cost (for inventory cost the sum of holding cost and stockout cost).

**Applied Research in Queueing**

Work was completed under support from the National Science Foundation on a three-year research project focusing on location of facilities on a network in a queueing environment. Here, a facility such as the home location for an ambulance or an emergency repair unit is located on a network so as to minimize the average response time to a random customer, where the response time is the sum of queueing delay and
travel time. Substantial new results were obtained this year in areas related to priority customer queues, "pruning" customers distant from the home location, "roving" servers in which the server is dispatched back-to-back from the previous customer's location, and location on tree-like networks.

Research was initiated on a three-year grant from the National Science Foundation on analysis of queueing delays and their environments. This research is predicated on the hypothesis that the customers' 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, include the queueing environment, information fed back to the customer about anticipated delays, and "social injustice." Social injustice is defined as a violation of the first-in, first-out principle. Two new quantities relating to social injustice were defined: "slips" and "skips." Any customer who arrives after a given customer in a queueing system and departs before that given customer has experienced a slip. Substantial results were obtained in deriving the probability distributions for numbers of slips and skips in popular queueing systems.

Public Sector Applications

Operations research applications in the public sector were developed by ORC faculty and students in the areas of criminal justice, urban services, and energy planning. 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 process quickly calls for police service from the public.

This applied research spawned new methodological results in queueing theory. New results were obtained for the multiserver prioritized queue with server cutoffs. In this system, when more than m servers of priority class i are busy, arrivals of priority i are refused immediate service and are queued. Performance characteristics, including waiting time distributions, were derived, and, for a given cost structure, the optimal number m for each priority class was determined. For transient queues, new approximations of expected queue length were derived using imbedded Markov chains.

Some initial research was undertaken in attempting to apply the concepts of "expert systems" to the area of urban police operations. In particular, certain aspects of the methodology of expert systems were applied to "diagnosis" of police emergency calls received over 911. Illustrative scenarios of "yes" and "no" sequences of questions were developed for such incidents as family disputes and barking dog complaints. Additional progress in applying expert systems to these areas was made in modeling the way police dispatchers select out-of-sector cars to assign to incidents when the in-sector car is already busy on a previous incident. This work married the ideas of spatial queueing systems and expert systems.

ORC faculty and students participated in a large project to build a national energy planning system for Argentina. The system has been completed and installed in Buenos Aires where it is in active use by energy companies. The system employs two operations research models linked by a price-directed decomposition scheme. A dynamic programming model was devised and implemented for optimizing drilling strategies in oil and gas fields, given prices the Argentine energy sector is willing to pay for primary fuels. A large-scale mixed integer programming model of the Argentine energy sector was devised and implemented for determining an optimal utilization of oil and gas supplies to meet end-use demands over a twenty-year planning horizon. The energy sector model included investment options for expanding the sector's infrastructure.

In the decomposition scheme, the energy sector model determines prices the energy economy is willing to pay for oil and gas at each basin and in each year of the planning horizon. These prices are fed to the dynamic programming model which determines optimal drilling strategies and associated supplies of oil and gas from each basin. The supply vectors are then fed to the energy economy model, and the process is repeated.

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 1984-85, 40 students were enrolled in these programs—25 PhD candidates and 15 SM candidates. Six master's degrees and five PhD degrees in Operations Research were conferred during 1984-85, and four more PhD degrees will be completed during the summer of 1985.

Students in the Operations Research Center represent a variety of backgrounds and countries. Nearly 50 percent of ORC students are were foreign countries; 30 percent of the students were women, a higher percentage than in any prior year. ORC students have attained considerable scholastic achievement, as evidenced by the number of fellowships and scholarship holders among them: several students hold scholarships from their respective countries; one student was awarded a National Institute of Justice Fellowship, and two students held Charles Stark Draper Fellowships. Other students have received departmental teaching awards.
The Operations Research Center achieved its goal of providing state-of-the-art, locally based "computer utility" environments for its students, staff, and faculty. The ORC now has state-of-the-art color and black and white graphics work stations and a variety of personal computers and word processing equipment. The graphics equipment includes color and black and white work stations by Apollo Computers and black and white work stations by the Xerox Corporation. Substantial progress was made by faculty and students during the year in demonstrating how logistical operations research model can be better displayed, analyzed, and optimized in a graphics work station environment. In one example, the "Hypercube Queueing Model" was implemented on the Apollo color graphics work station, and output was displayed in totally visual (nonnumerical) form. We foresee substantial additional progress in this area in the future. Other logistical models were implemented on these computers in a "simulation animation mode," thereby greatly facilitating the users' and the analysts' understanding of systems operations.

Both of the Operations Research Center Codirectors were involved in the organization of professional society meetings. The TIMS/ORSA (The Institute for Management Science/Operations Research Society of America) Joint National Meeting was held in Boston in April 1985 and was organized under the general chairmanship of Richard C. Larson. Registration for this meeting was at an all-time high of 1776 participants. The 12th International Symposium on Mathematical Programming will be held at MIT in August 1985, and it has been organized with Jeremy F. Shapiro as general chairman. This conference is anticipating record-breaking attendance, as well.

The Operations Research Center regularly offers professional courses during the Summer Session. In the summer of 1984, four such programs were offered—"Resources Management: A New Approach to Corporate Planning"; "Decision Analysis: Basic Concepts and Applications"; "Decision Analysis with Multiple Objectives: Concepts and Applications"; and a new course, offered for the first time in 1984, "Operations Management in the Services Industries."

The ORC Seminar Series was privileged to have speakers from business and industry as well as from academia this year. Among the operations research professionals who made presentations, we had Narendra Karmarkar, from AT&T Bell Laboratories, Alexander Rinnoy Kan, from Erasmus University, Rotterdam, The Netherlands, David Shmoys from Harvard University, and Mark Brodie from Columbia University. In addition to the regular seminar series, the Operations Research Center initiated and hosted the Transportation Logistics Seminar Series, during which various project directors described their current research at MIT in the area of transportation logistics.

RICHARD C. LARSON
JEREMY F. SHAPIRO
CODIRECTORS
Project Athena

INTRODUCTION

Project Athena is a five year program initiated in Academic Year '83-'84 to explore the innovative use of computation in university educational programs. The project's primary objective is to improve the education MIT provides to its undergraduate and graduate students. Athena will combine $50 million in hardware, software, maintenance, and staff from Digital Equipment Corporation and IBM with $20 million to be raised by MIT to achieve this objective.

Athena also has some important secondary objectives including:

- to establish a base of experience in using computers in different ways that is sufficient for MIT to make well-informed decisions about educational computing in the future;
- to create a computational environment that can accommodate equipment made by different computer manufacturers without imposing large costs on users or developers of educational software;
- to encourage the sharing of ideas, program code, data, and experience across the entire MIT community;
- to develop computer-based learning tools which can be used by other universities.

Attaining these goals has produced a design for Athena that has a number of distinctive characteristics. First, in order to affect the curriculum fundamentally, computational resources must be made similar to other utility-like services provided on campus, i.e., they must be ubiquitous.

The size of the potential user community made use of a single, large mainframe infeasible. Instead, a system of distributed microcomputers was selected, each capable of supporting most of a single user's computational needs.

It was decided that simply providing a campus-wide system was likely to be insufficient to yield a fundamental change in instructional approaches. We also chose to provide faculty with the opportunity to obtain funding for educational projects that used Athena. These funds are intended to support faculty salaries, student assistants, and other expenses related to the projects. This internal grant program is administered by faculty/student committees whose membership reflects the diversity of the MIT community. We anticipate spending $10 million over five years for curriculum development.

The desire to create an environment that encouraged sharing of information and expensive services such as graphics output and large data bases led to the design of an integrated, campus-wide network of computers, each of which could freely communicate with the others at extremely high speeds. This network will be implemented in stages over the course of the project.

The desire for a system that was as manufacturer-independent as possible and that allowed users to share programs easily led to the concept of coherence. Coherence has two distinct aspects. First, users of the system should have one or more powerful, easy-to-learn modes of interaction with the system which are as invariant as possible over different types of hardware. These interfaces should be available at all levels, including the operating system and applications programs created by faculty for student use. Second, one program should be able to obtain services from and provide services to other programs, regardless of the computer languages in which they were written and the machines on which they are run. For example, if one faculty member writes a large numerical package in Fortran, a user of the Athena system should be able to draw upon that package (as a "service") even if he or she is working in Lisp on an entirely different computer.

Finally, it should be stressed that Project Athena is an experiment. We envision exploring a very wide range of uses of computers in education, some which will prove effective and other which may well fail. It is a clear part of Athena's mission to encourage innovative concepts with the goal of learning how computation can be effectively used in the educational process.

The remainder of this annual report is divided into five sections:

- a review of the status of faculty/student projects under Athena
a description of the Athena staff

a summary of the software facilities we have now and will provide in the near future

a report on the equipment we now have operational and will be installing in the next year

FACULTY/STUDENT PROJECTS

To date, 69 curriculum development projects have been approved for funding by the Athena Executive Committee. These projects arose from four cycles of proposal submission, internal review by the Athena Resource Allocation Committees, and final funding approval. A total of approximately $3.3 million has been allocated to these projects. In addition, there are a substantial number of faculty and students undertaking projects using Athena's computational resources but not receiving direct financial support.

Of the 69 projects, 29 are in the School of Engineering, nine in the School of Humanities and Social Sciences, 12 are in the School of Architecture and Planning and 13 are in the School of Science. The remaining six projects involve more than one school or organizations such as the Office of the Dean of Student Affairs which are not affiliated with any particular school at MIT.

Many of these projects have already begun using new educational materials in the academic program. Last semester, approximately 1,600 students were enrolled in the 47 subjects that made direct use of Athena's computer facilities.

PROJECT ATHENA'S STAFF

Project Athena's staff has expanded considerably since its beginnings. It consists not only of MIT employees, but also includes staffs from Digital Equipment Corporation, IBM, Codex, and Bolt, Beranek and Newman. Including the industrial participants in the project and operations support groups from MIT's Information Systems group, approximately 45 people (or full-time equivalents) are directly involved in Athena. In addition, Athena has approximately 70 part-time student employees.

This past year, Athena and MIT Information Services (IS) agreed that operational support (hardware installation, maintenance, software release engineering, etc.) would be provided by Information Services. A separate group within IS with offices in the Athena staff area was created for this purpose.

ATHENA SOFTWARE

The evolution of Athena's computing environment is logically divided into two phases. In the first phase, we are primarily making use of existing software and hardware from IBM and Digital, accepting some of the intrinsic incoherencies this produces. Key features of the system standardized across the entire system in Phase 1 include network protocols, programming languages, and editor.

The first phase Digital hardware consists of 54 VAX 11/750's with a mix of about 300 graphics terminals running the BSD 4.2 version of the UNIX operating system. The first phase IBM equipment consists of 145 PC/XTs and 160 PC/ATs running PCDOS. Software is provided under PCDOS to provide the same network protocols, programming languages, and editor as appears in our UNIX environment.

The second phase of Athena will be built entirely on the UNIX operating system, with each vendor providing high performance, single user, graphics workstations. Specifications for these workstations include a 32 bit processor capable of executing on the order of 1 million instructions/second, a bit-mapped graphics display with nearly 1 million pixels, more than a megabyte of memory, a high speed network attachment and some form of pointing/selecting device (e.g. a "mouse"). We expect this phase to begin in the coming academic year.

ATHENA FACILITIES

Project Athena's first computer facility opened for use by faculty/student curriculum development projects in March, 1984. By June, 1984 there was sufficient capacity to provide access to all MIT faculty. In September, 1984, about 57 academic subjects used Athena. In March, 1985 all undergraduates were given access to the system.

Athena now has 12 clusters scattered across MIT in Buildings 1, 2, 4, 6, 9, 11, 16, 24, 38, 66, E40 and W20. These range in size from eight workstations up to the Student Center facility, which will eventually have 60 workstations. All of these facilities are networked through the MIT campus-wide network.

Plans for the coming academic year will create four new major facilities and a still-undetermined number of small areas dedicated exclusively to curriculum development projects. All of these facilities will be based on Phase 2 equipment.
Beyond next year, Athena will deploy equipment in classrooms, living groups, laboratories, libraries and other areas around the Institute.

For further information on Project Athena, including its genesis, overall funding, and current curriculum development programs, see An Introduction to Project Athena, a booklet published in Fall, 1983, and Faculty/Student Projects, a booklet published in March, 1985. Copies are available from Project Athena in Building E40 at MIT.

STEVEN R. LERMAN
ROTC Programs

The Reserve Officer Training Corps (ROTC) programs at MIT are strong and vibrant. Students at MIT, Harvard, Tufts, and Wellesley continue to find the MIT ROTC programs a valuable conduit for providing them substantive educational opportunities, leadership skills, and financial support. The Navy's enrollment figures for 1984-85 displayed some growth over last year with a 6.8% increase while the Army (-3.8%) and Air Force (-17.5%) each experienced a decrease in enrollment from 1983-84.

One of the strong attractions to the ROTC programs is the financial support that the services provide to the students in the form of scholarships. Of the 41 MIT students enrolled in the Army ROTC program, 37 were scholarship recipients. The Air Force ROTC program had 211 of their cadets on scholarships.

Enrollment in the three ROTC programs at MIT in the fall of 1984 was as follows:

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>YEAR I</th>
<th>YEAR II</th>
<th>YEAR III</th>
<th>YEAR IV</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Army</td>
<td>19</td>
<td>24</td>
<td>24</td>
<td>11</td>
<td>78*</td>
</tr>
<tr>
<td>Navy</td>
<td>77</td>
<td>57</td>
<td>29</td>
<td>24</td>
<td>187**</td>
</tr>
<tr>
<td>Air Force</td>
<td>62</td>
<td>63</td>
<td>49</td>
<td>54</td>
<td>228***</td>
</tr>
<tr>
<td>TOTALS</td>
<td>158</td>
<td>144</td>
<td>102</td>
<td>89</td>
<td>493</td>
</tr>
</tbody>
</table>

*Includes 37 students cross-enrolled from Harvard University (19), Tufts University (9), and Wellesley College (9).

**Includes 75 students cross-enrolled from Harvard University (5), Tufts University (23), and Wellesley College (2).

***Includes 66 students cross-enrolled from Harvard University (24), Tufts University (34), and Wellesley College (8).

Seventy-nine seniors received commissions during the year with the following distribution: Air Force (50), Army (11), and Navy (18).

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 150 cadets receiving awards from 60 different organizations. President and Mrs. Gray and several MIT representatives, along with representatives of the Harvard, Tufts, and Wellesley administrations attended the banquet. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, Field Day, other Athletic competitions, and on May 2nd, the Annual Tri-Service Pass and Review, and Parade with President Gray as the reviewing officer.

Cadets from the three services made trips to Washington, D.C., Eglin AFB, Florida and Nellis AFB, Nevada; and Cadet Stuart Cobb III represented MIT as a delegate to the 27th Air Force Academy Assembly in Colorado Springs, Colorado.

There were some major personnel changes during the academic year:

- Colonel Emmanuel J. Scivoletto became the Professor of Aerospace Studies in September; Captain Hugh Beemer and SSgt Larry Moody arrived for duty in August; Major Steve Wallace retired in January after 20 years of active duty; TSgt John MacPherson will retire at the end of August after 20 years of active duty; Major Laura Counts will transfer to Maxwell AFB, Alabama to attend the Air Command and Staff School.

- Captain C. Graham, Commanding Officer, NROTC and NAU, MIT, was relieved by Captain V.P. McDonough in September 1984; CDR R.J. McClure, Executive Officer, NROTC and NAU, MIT, was relieved by CDR J.G. Ward in June 1985.
The ROTC Faculty Committee, under the co-chairmanship of Professor Robert MacMaster and Professor David Roylance, continued to provide timely advice and support for the ROTC programs. Special thanks also go out to Lieutenant Colonel James P. Hassett, Visiting Professor and Director of the Office of Military Science; D.E. Guza, Acting Commanding Officer, Navy ROTC and NAU; and to Major Joseph P. Bisognano, USAF for providing helpful information for this report.

JOHN B. TURNER
In the mid-1960s, Congress created the National Sea Grant Program to further the innovative and prudent use of ocean and coastal resources. Similar to the Land Grant Program, established a century earlier, Sea Grant integrates research, education, and public service through an affiliation of government, universities, and private industry. To support Sea Grant, the federal government provides a basic appropriation which is distributed through a grant process, administered by the National Office of Sea Grant in the National Oceanic and Atmospheric Administration. Nationally, 29 programs have been established; each is expected to match its grant from non-federal sources. This matching system of support helps to keep programs attuned to the educational and research needs of its constituents. At the same time, by encouraging cooperation between those who will do the research and those who will use it, the system also fosters more efficient technology transfer. Last year MIT received a grant of $1.7 million; $1.3 million in matching funds were provided by industry, local and state governments, and the Institute. In addition, Sea Grant administered $399,000 in research support from several federal agencies for faculty, students, and staff.

**Research**

In the 1984-85 academic year 18 faculty members from 4 departments participated in Sea Grant's research program. The focus was on four principal areas—offshore facilities, unmanned-underwater work vehicles, coastal processes, and living resource development. Projects were selected in a proposal process which included review by an MIT faculty committee, several industry committees, and peer critiques.

For several years, offshore facilities has provided a research thrust of particular importance. As oil and gas recovery move further offshore and northward to the Arctic, industry and university engineers have been pressing to understand the requirements of new environments to design, build and maintain structures safely, efficiently and cost effectively. Several projects studied the wave climate in these new environments. In the Department of Civil Engineering, unique research is being done using a series of experiments to improve methods for predicting wave breaking forces on surface-piercing structures. Department of Ocean Engineering faculty and students are creating a design procedure to predict the amount of local damage to ships and structures from hydrodynamic impact loading. They are also developing a complete, consistent theory for second-order wave forces which will provide a data base of computational results for design use.

MIT's geotechnical research has helped to establish industry standards and procedures for foundation design. In the last year, research in the Constructed Facilities division of the Department of Civil Engineering aimed to enhance current knowledge of new piles and soils behavior under cyclic loading. Fundamental studies were also undertaken to overcome engineering obstacles in building upon large, open-ended piles. To develop guidelines for reliably measuring the engineering properties of Arctic silts, laboratory experiments on representative undisturbed soil samples were used to help evaluate and compare existing geotechnical data and performance.

The use of cables and flexible risers is increasing as compliant structures are beginning to replace fixed jacket platforms. Researchers from the Department of Ocean Engineering anticipated this need and have started a major program to investigate the static and dynamic behavior of compliant risers to aid engineers in discerning the effects of principal variables and evaluating alternative concepts. Another project established a complete understanding of elasticity effects on cable behavior.

Some construction and maintenance tasks will fall to unmanned vehicles in cold and deep water environments. To make undersea robots effective replacements for human divers, MIT Sea Grant has been pioneering technology for several years. In the last year, a team of 15 undergraduate students from several departments spent thousands of hours building and equipping a test vehicle in the Department of Mechanical Engineering Man-Machine Systems Laboratory. The 900 pound vehicle, released on a 1200 foot tether from the Institute's research vessel EGRGTON, will be used to test concepts in supervisory control, telemanipulation, and underwater welding. Much of the support for this project came from industry. A supervising engineer was given a six month sabbatical by his company to work at MIT on the project, a major oil company through UROP contributed the money to pay some student salaries, and vehicle parts were provided by various local and national ocean engineering firms.
The concepts being tested by the vehicle will have applications not only for the offshore industry but also for understanding marine ecosystems in the coastal zone. The Institute's faculty through the Sea Grant Program continues its interest in defining the consequences of human activities on nearshore environments. In the Department of Civil Engineering Ralph Parson Laboratory researchers have been seeking greater knowledge of pollutant movement in Boston Harbor, a subject which is critical to waste disposal decisions. Other faculty and students in the last year worked in a Boston salt marsh to quantify the water, salt and heat balance of a marine area subjected to intense human disturbance. The results of the research will provide insights into the feasibility of filtering some municipal wastes through marshland, thus making them more productive and providing a natural cleansing system for the wastes themselves. In the same laboratory, researchers worked to develop a state of the art wind-wave model that will be useful to structural designers in forecasting the impact of severe storms on coastal and offshore facilities.

Since its founding, the Institute has been associated with cutting edge research. So it is with biotechnology. Advances in that emerging field are being applied at MIT through the Sea Grant Program to find ways of using fish wastes for medical purposes. Researchers in the Department of Applied Biological Sciences worked on a project to isolate bioactive compounds from sharks which have known uses in inhibiting certain kinds of cancers.

ADVISORY SERVICES

The organization of Sea Grant's advisory service reflects the Institute's long-standing commitment to public service and technology transfer. Three elements, the Marine Industry Collegium, the Massachusetts Marine Liaison Service and the Communications/Information Service, have helped to establish open communication between the marine community and the faculty and students at MIT.

The Sea Grant Collegium was the first to be established at MIT and remains one of the largest and most active groups fostering industry-Institute cooperation. In the last year this group orchestrated the support to build the underwater robot described earlier in this report. Members of the 1984-1985 Collegium attended a workshop to discuss Institute-wide robotics research. At other workshops they reviewed work at MIT and Woods Hole on the future of remote sensing and oceanographic instrumentation, wave forces on offshore structures, and the Sea Grant Lecture Seminar on Ocean Disposal of Public Wastes. Besides the workshop series, Collegium services also include introducing members to faculty who share specific technical interests, providing research reports, and obtaining financial and in-kind support for MIT researchers.

The Massachusetts Marine Liaison Service (MMLS) continued this year to help to direct the Massachusetts Marine Fisheries Training Program, a joint effort of the Institute and the Massachusetts Maritime Academy. In its ninth year, the program offered classes on topics ranging from electronics to survival techniques for commercial and recreational fishermen. MMLS also coordinated the Center for Fisheries Engineering Research, a research and training program which has contracted with the David Taylor Naval Ship R&D facility in Bethesda Maryland to test new trawl designs and demonstrate their application to professional fishermen. An MMLS staff member completed a sociological study for the New England Regional Management Council on the economic impacts of new regulations on fishermen. Although required by federal law, this is the first analysis of its kind that has been done for a management council.

In the past year the Communications/Information Center released 25 new reports. These publications are housed with over 300 other MIT Sea Grant reports in the Marine Resource Information Center. This small reference facility helps the MIT community and the public gain easy access to the Program's past and current research. An electronic data base, created by the Information Specialist, has made it faster and more efficient to create extensive bibliographies on marine research underway at the Institute and throughout the national Sea Grant network.

EDUCATION

Sea Grant provides services and educational opportunities for MIT students, professionals in the marine field, and the public through a variety of programs. In this last year, two major conferences attracted several hundred participants to explore issues related to marine policy. The first meeting, "Conflict Resolution in the Coastal Zone and Offshore" was held in November, 1984 in cooperation with the Department of Ocean Engineering and the Alfred P. Sloan School of Management, and in April, 1985 the Department of Civil Engineering joined with the program to hold the 12th Annual Sea Grant Lecture and the 4th Annual Sea Grant Seminar. The focus was on "Ocean Disposal of Public Wastes," an issue of current concern locally and nationally. The proceedings of the 1st and 3rd annual Sea Grant Seminars on biotechnology in the marine sciences have
attracted the attention of a Congressional committee and are expected to be instrumental in eliciting an appropriation for a major marine biotechnology initiative within the next year. In the last year support for UROP students doubled, allowing some undergraduates to work on existing Sea Grant projects and allowing others to explore new areas of interest and usefulness to the marine community.

PROGRAM MANAGEMENT

Chryssostomos Chryssostomidis, Professor in the Department of Ocean Engineering is the Director of Sea Grant. He is assisted by Associate Research Directors Marcus Karel, Professor in the Department of Applied Biological Sciences, and Keith D. Stolzenbach, Associate Professor in the Department of Civil Engineering. The Associate Director for Education is E.R. Pariser. Norman Doelling serves as Executive Officer and Manager of the Marine Industry Service Collegium. Arthur B. Clifton is Manager of the Massachusetts Marine Liaison Service, Elizabeth T. Harding is Manager of the Communications/Information Service, and Lawrence W. McKinnon is the Administrative Officer.

Sea Grant administers the Doherty Professorship endowed by the Henry L. and Grace Doherty Foundation for untenured faculty at the Institute. In the spring of 1985 Dick K. Yue, Assistant Professor in the Department of Ocean Engineering and Triantaphyllos R. Akylas, Assistant Professor in the Department of Mechanical Engineering, were named recipients of the chair. The Dean A. Horn Award, a grant established to honor the former Director of the MIT Sea Grant Program, was given to an undergraduate in the Department of Ocean Engineering, George C. Kriezis.

CHRYSSOSTOMOS CHRYSSOSTOMIDIS
Summer Session

Special 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 1983 - 1,463 registrations in 46 special programs
Summer 1984 - 1,826 registrations in 67 special programs

Foreign citizens comprised approximately 11 percent of the registrations.

Regular Subjects

Graduate students comprise 80 percent of the student body in summer. The 1983 registration of 2,616 students was a decrease from the 2,707 in 1982.

FREDERICK J. MC GARRY
Technology and Development Program

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;
- Explore opportunities to undertake cooperative investigations with government, academic, or private organizations and institutions.

The Program 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.

Highlights of the Past Year

TDP activities over the past year focused on clarification of objectives, diversification of activities, and exploration of potential areas for future involvement. In recognition of the growth in the Program's scope and depth of involvement at MIT, its name was changed in September 1984 from the Technology Adaptation Program to the Technology and Development Program. Efforts were made to assess the achievements of the past several years, identify the unique aspects of the Program at MIT, and establish new contacts and institutional ties with developing country and international organizations concerned with science, technology, and development. At the same time, the Program's major collaboration with Cairo University entered into its eighth year, having received since its inception in 1977 a total of $29.2 million in support from the U.S. Agency for International Development.

The following sections of this report summarize the specific activities undertaken in 1984/85.

Major New Initiatives

At present, the TDP has accumulated almost 15 years of experience as the focal point at MIT on science, technology, and development. It has conducted both highly specialized and multi-disciplinary research projects, specific country programs, and regional studies, as well as a major sustained exercise in institution building with Cairo University. Several educational programs have been undertaken in tandem with the research, including conferences, seminars, short courses, and visits by distinguished international scholars and government officials. Over 60 MIT faculty members from 13 departments have participated, and over 160 research assistantships have been provided to MIT graduate students.
Therefore, at this point the TDP is seeking to capitalize on these achievements through initiatives intended to:

- Establish new institutional ties and strengthen existing ones with foreign, U.S., and international organizations with similar concerns.
- Explore new mechanisms for collaboration with these institutions.
- Seek new sources of financial support for research and educational activities at MIT which will further TDP's objectives.
- Expand the scope and base of TDP involvement at MIT.

The most significant activity in this regard was the initiation of a series of international roundtables, with a regional focus, to discuss the various issues of concern in the application of science and technology to development. The first was held on "Science, Technology, and Development in the Arab World" at Endicott House in October 1984. Joint sponsorship was provided by two key institutions in the region, the Arab Monetary Fund and the Arab Fund for Economic and Social Development. Representatives from several distinguished educational institutions and government agencies attended from six Arab Countries. The U.S. State Department and U.S. Agency for International Development were also represented. In addition to the discussions, the group was addressed by Dr. Paul Gray, Dr. David Saxon, and former U.S. Ambassador to Egypt Dr. Hermann Eilts.

The stated objectives of the Roundtable were:

- To review major developments in science and technology in the Arab World over the past decade.
- To survey the institutional developments and the investment strategies in science and technology.
- To explore the priorities of different Arab countries in that area.
- To identify potential areas of cooperation with leading international institutions such as MIT.
- To focus on select areas of advanced technology and select economic sectors in order to enhance this cooperation.

The participants exchanged views on the above, discussed steps for enhancing communication and collaboration, and explored various institutional models for sustaining development. Of particular relevance to the TDP were the discussions on the importance of cooperation among universities in developed and developing countries. The participants confirmed that universities have a key role to play, not only in the training of future scientists and technologists, but also in upgrading indigenous science and technology infrastructures as a whole. The program conducted by MIT and Cairo University over the past eight years provides a particularly significant example of what can be achieved through inter-university collaboration.

The Proceedings of the Roundtable have been published, and are available from the Technology and Development Program Office, room E40-247.

The second roundtable, to focus on similar topics in Latin America, has been scheduled for October 1985. The Tinker Foundation will be co-sponsoring this event, and has provided a substantial portion of the necessary funding. The Organization of American States and the Inter-American Development Bank have confirmed their participation.

As a result of the meetings held during the Arab roundtable, the Rector of the University of Jordan, the Rector of Yarmouk University (Jordan), and the President of Jordan's Royal Scientific Society visited the Development Research and Technological Planning Center (DRTC) at Cairo University in October 1984. There they reviewed the results of the collaborative program between MIT and Cairo University, and possibilities for future cooperation with their respective organizations. Representatives were also sent from these Jordanian institutions to the DRTC Technical Conference in Cairo in January 1985.

The TDP continued to pursue possible collaborative activities with the Technical University of Berlin (TUB), the Technical University of Lisbon (UTL), and the Middle East Technical University (METU) in Turkey. The President of UTL, Professor E.R. Arantes e Oliveira visited Cambridge in November 1984 to confer with members of the TDP Policy Committee, and to meet with several prominent Portuguese organizations in New England. A potential program between TDP, UTL, and selected Brazilian universities was discussed and a proposal submitted to the Tinker Foundation.
The Proceedings of the "Conference on Science and Technology in Socioeconomic Development" were published jointly by TDP and the Technical University of Berlin in the fall of 1984. This conference, held in Ankara in June 1984, brought together representatives from TUB, MIT, and the Middle East Technical University to discuss issues of concern to the scientific and technological community of Turkey, as well as a proposed collaborative program between TUB, MIT, and METU. Professors Nazli Choucri, Fred Moavenzadeh, and Nafi Toksoz attended from MIT.

In April 1985 a delegation from Kuwait headed by its Ambassador to the U.S. visited MIT and met with Dr. Paul Gray and Professor Fred Moavenzadeh of TDP. Possible collaborative activities between MIT and Kuwaiti universities and research institutions were discussed. A follow-up meeting was held in May between Professor Moavenzadeh and officials from Kuwait University to discuss a specific framework for cooperation.

The University of the United Arab Emirates also sent a delegation to MIT in May 1985 headed by the Chancellor of the University, to discuss a possible joint research venture with TDP.

Discussions have taken place between TDP, the MIT Industrial Liaison Office, and the Maravan Oil Company in Venezuela. A conference is planned there in November 1985 to outline the specific objectives and scope of a joint program.

The Chief Advisor to the Minister of Science and Technology in Brazil visited the TDP to discuss opportunities for collaborative work.

The newly formed Indonesian Institute of Technology (ITI) sent a delegation to MIT in June 1985, to discuss ways in which MIT and the TDP could assist in developing this institution and promoting its contribution to the science and technology infrastructure of Indonesia. Topics discussed included curriculum development, methodology of scientific/technological instruction, laboratory and facility development, and staff development.

Cairo University/MIT Technological Planning Program

In recognition of the efforts that have been made by MIT in the CU/MIT Technological Planning Program, Dr. Paul Gray was awarded an honorary doctorate degree by Cairo University in January 1985. At a ceremony attended by several Egyptian dignitaries and the acting U.S. Ambassador to Egypt, Cairo University President Dr. Hassan Hamdi praised Dr. Gray for his dedication to international cooperation in education and scientific research. Dr. Gray responded that the scientific community is an international one, and therefore open communication and the free exchange of ideas are essential to the quality of scientific and technological enterprise. He commended the CU/MIT Program for attempting to build a new model for collaboration between front-rank universities in nations at different stages of industrialization. Dr. Gray pointed out three critical elements which had contributed to the success of the program: (1) the strong contribution of faculty and students from both universities, (2) the fact that new knowledge and other benefits have been equally conferred upon participants from both universities, and (3) the continuity of financial support provided by the U.S. Agency for International Development since the program's inception in 1977.

In 1984/85, the CU/MIT Program focused on the continuation of several joint CU/MIT research efforts, educational activities, and on further institutional growth of the Development Research and Technological Planning Center (DRTPC) at Cairo University. Through the combined efforts of the Technology and Development Program and participating faculty at Cairo University, the DRTPC now provides an institutional mechanism at CU for conducting contract research on development topics with Egyptian ministries, public and private sector companies, and international organizations. Prior to the establishment of the DRTPC, virtually all sponsored research performed by Cairo University faculty members had been done on a private consulting basis. Based on the model of MIT programs such as TDP, the DRTPC now provides access to the resources of Cairo University as a whole, and offers research support services and a framework for conducting education and research dissemination activities. In addition, it has fostered a new interest on the part of CU faculty members in performing development-related research and mobilizing their capabilities on behalf of Egypt's national development efforts.

The CU/MIT Program is now one of several research programs administered by the DRTPC. Since 1979, over 30 major projects have been conducted on behalf of 22 Egyptian government and private sector organizations, and four international organizations, including the World Bank, the International Labor Organization, and the U.S. Agency for International Development. Current research topics include operating scenarios for the Aswan Dam, an energy management computer program at the Egyptian Iron and Steel Company, and traffic management scenarios in the Heliopolis suburb of Cairo. Faculty participants at the DRTPC have been drawn from the Cairo University Faculties of Engineering, Economics and Political Science, Medicine, Science, and Commerce. The DRTPC itself has established six operating divisions, including a computer center and a library, and has an administrative staff of 38.
In 1984/85 MIT participation in the CU/MIT Program included 15 faculty members, 10 research associates, and 13 graduate research assistants from six academic departments at MIT. The specific activities funded by the program over the past year have included the following:

**Long Term Research Projects**

Since 1977 over $7.3 million has been allocated by TDP to academic departments at MIT for CU/MIT research projects. During the past year, two new projects were initiated in the following areas:

**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.

**Freight Service Planning and Marketing**

The Egyptian Railroads organization is seeking to improve its marketing and planning capabilities in order to increase its share of the Egyptian freight transportation market. Various organizational improvements are being considered, especially with respect to equipment and facility utilization, and overall coordination among the various operating units. Upgraded management information systems are being developed, along with computerized models and other analytic techniques that can be used by management and operating staff. The impact of various low-cost investment schemes on overall efficiency and profitability is also being considered. MIT Principal Investigators: Professor Joseph Sussman and Dr. Carl Martland, Department of Civil Engineering.

Six projects were continued from previous years:

**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.

**Water Resource Planning Models**

This project has investigated and evaluated various techniques for planning and managing Egypt’s water resources. Project efforts, which originally focused on the operation of the High Aswan Dam, have been expanded in recent years to include more extensive areas of the Nile Valley, the Upper Nile, and the Delta. In 1984/85 the MIT portion of the research shifted toward modeling of the entire Nile Basin, so that Egypt and the other six Nile Basin countries can more effectively evaluate options for the basin as a whole. MIT Principal Investigator: Professor David Marks, Department of Civil Engineering.

**Engineering Applications for the Egyptian Plastics Industry**

The objective of this project is to provide a technological base for use of composite materials by the plastics industry in Egypt, and to develop improved materials and processing methods for enhanced durability in applications such as pipes. The resistance to brittle fracture of PVC and other plastic pipe materials has been studied and a clear understanding of the fracture process has been established. Fatigue resistance of these materials has also been investigated. Data is now being evaluated to characterize the fatigue behavior of several classes of short fiber reinforced plastics which are expected to be of future importance in engineering applications in Egypt. MIT Principal Investigator: Professor Frederick McGarry, Department of Materials Science and Engineering.

**Energy-Economy Interaction and Energy Policy**

A set of analytical models has been developed to provide a comprehensive view of policy issues and performance in the energy sector of Egypt. These have included (1) the Egyptian Petroleum Model to
examine oil production and the impacts of investment and extraction decisions, (2) the Egyptian Natural Gas Model to identify the best uses of natural gas and the socially optimal prices for these uses, and (3) the Short-Run Energy Macroeconomic Model for Egypt, to explore, identify, and understand the uses of energy within the different sectors of the economy, and the ways in which policies in one sector affect other sectors and their output. MIT Principal Investigator: Professor Nazli Choucri, Department of Political Science.

Energetics in the Egyptian Metal Industries

Energy consumption in the Egyptian iron and steel industry has been at higher levels than international industrial norms. This project undertakes comprehensive analyses of material and energy consumption for each of the various processes in the production of crude steel. Current work involves technical and economic feasibility analysis of recommended solutions, to achieve improvements in productivity, product quality, and energy conservation. MIT Principal Investigator: Professor David Gordon Wilson, Department of Mechanical Engineering.

Intercity Multimodal Transportation Model

The Egyptian Ministry of Transport is presently engaged in a comprehensive effort to overhaul its transportation infrastructure and strengthen its capabilities in investment planning and evaluation, and in formulation of effective maintenance, operating, and pricing policies. Through this project, techniques have been developed to analyze the effects of alternative transport policies on various intercity transport modes in Egypt. An analytical framework has been developed (Intercity Transport Model) that forecasts the overall performance of the transport sector in terms of operating efficiency, revenues, costs, and user benefits. In addition, technical, operational, and financial evaluation measures have been established for each of the separate transport modes (railways, highways, and waterways). MIT Principal Investigator: Professor Fred Moavenzadeh, Department of Civil Engineering.

Short-Term Research Projects

One short-term project was conducted in 1984/85, under the direction of Professor Daniel Holland of the Sloan School of Management. Entitled "Assessing the Institutionalization Process of the DRTPC," it focused on an analysis of various models of institutional development and organizational evaluation, with special reference to university-associated research centers. A report was prepared which summarized various models constructed to date, proposed a model for the DRTPC, and suggested specific methods for evaluating the viability and effectiveness of the DRTPC as it continues to grow as an institution.

Postdoctoral and Doctoral Fellowships at Cairo University

As part of the CU/MIT Program, thirteen Cairo University faculty members and six graduate students were awarded fellowships in 1984/85. Research topics were approved on the basis of both academic content and relevance to the development needs of Egypt. Consistent with the CU/MIT Program's objective of broadening its base of involvement at Cairo University, participants were selected from ten academic departments at Cairo University, from the Faculties of Economics and Political Science, Commerce, Medicine, Science, and Engineering.

Research Development Support for the DRTPC

In order to increase and diversify the sponsored research activities of the DRTPC, during 1984/85 the CU/MIT Program provided support to several Cairo University faculty members for proposal preparation activities. As a result, proposals were submitted to the Ministries of Electricity and Energy, Transport and Communications, and Housing. MIT participation was notable in one of these efforts; namely, development of an action plan to improve the performance of prefabricated housing companies in Egypt. MIT Professors Eric Dluhosch, Waclaw Zalewski, and Ranko Bon of the Department of Architecture visited Cairo to inspect various production facilities and construction sites. A workshop was held at the DRTPC for 20 high level management and technical personnel to discuss the preliminary results. A two year study has been proposed, to formulate architectural engineering solutions, and implement specific operational improvements to upgrade the performance of this sector.

Conferences, Seminars, Short Courses

The CU/MIT Program and the DRTPC continued their series of conferences, seminars, and short courses during 1984/85. Several research projects held seminars to review the status of their work. The Sixth Annual Technical Conference of the DRTPC was held in January 1985, at which the results of the joint CU/MIT research projects were presented and discussed. A nine-week short course on advanced investment planning and project evaluation techniques was held at the DRTPC in the fall of 1984, and was sponsored by the General Authority for Investment and Free Zones in Cairo. A seminar was held in June 1985 on the
determinants and consequences of international migration for the Egyptian economy. Professors Nazli Choucri and Myron Weiner of the Department of Political Science attended the seminar from MIT.

**Research Support Systems and Administrative System Development**

A further aspect of the CU/MIT Program is the development of appropriate systems at the DRTPC for its educational and research activities. During 1984/85 activity continued on library, computer and financial management system development.

**Computer:** Although development of the DRTPC’s computer facility was slowed during 1984/85 because of staff turnover, efforts continued to evaluate the potential usage of the VAX 11/780 system provided by MIT in 1982. Some of the possibilities discussed were advanced computer courses for Cairo University graduate students, the increased use of microcomputers at the DRTPC, and software sharing agreements with other VAX facilities. Two major software packages, IMSL and SPSS, were purchased by MIT and installed on the DRTPC computer.

**Library:** Efforts focused on upgrading the core collection and acquiring standard reference materials in the areas of interest to the DRTPC. Faculty principal investigators participated in a major acquisitions project.

**Accounting and Financial Management:** With the assistance of the MIT Comptroller, Mr. Philip Keohan, and two of his senior associates, Mr. John Donahue and Mr. Richard May, the DRTPC made significant advances in the areas of accounting and financial management. A detailed proposal was prepared to support negotiations for a Cairo University indirect cost rate with the U.S. Agency for International Development. The rate, which was subsequently approved, is now applied to all DRTPC research projects. A system of cost centers was developed and implemented at the DRTPC, to pool its core administrative costs and allocate them to its various research projects. Finally, work continued on computerizing the DRTPC’s entire accounting and financial management system.

**Future MIT Collaboration with Cairo University**

At a meeting between Dr. Paul Gray, the USAID/Cairo Mission Director, and the Egyptian Prime Minister, a potential new program between Cairo University and MIT was discussed, to focus on productivity and profitability in Egyptian public sector enterprises. A follow-up meeting was held by CU/MIT Executive Committee members and the Egyptian Minister of State for Cabinet Affairs and Administrative Development. This program would be integrated into the existing CU/MIT Program, and would involve an extension of the program to 1988/89.

In addition, meetings took place at MIT and in Cairo in May/June 1985 to formulate plans for the remaining period of the current CU/MIT Program contract with USAID, and discuss the possibilities for additional funding and time extension for the existing set of activities.

With regard to specific research plans for 1985/86, it was decided that since a possibility exists for extension of the program, the ongoing research projects should continue for another year at a lower level of funding. In this way, the continuity of the research effort will not be disrupted and valuable contacts will be maintained. This necessitated budget adjustments in other program areas, especially at MIT.

**Other TDP Activities at MIT**

The TDP continued publication of its newsletter, "Technology and Development". A special issue focused on energy issues in the developing world.

The Energy and Development Seminar Series was continued at MIT during the fall 1984 semester. The seminars are held to increase interaction between the MIT community and energy policy analysts from industrial, academic, and government institutions in the U.S. and overseas.

Eight publications were issued in the TDP Technical Report Series. A list of publications in print is available from the TDP Office, room E40-247.

Because of a reduction in the amount of funds currently available, the TDP administrative staff has been reduced. The position of Technical Officer has been eliminated, and two administrative support positions were combined.

FRED MOAVENZADEH
Fifteen years of undergraduate participation in faculty research throughout the Institute were celebrated in an article in the November-December 1984 issue of Technology Review entitled "UROP at 15", subheaded "MIT's Unique Program Endures Because It Pleases All of the People All of the Time." Again this year undergraduate Research Opportunities Program (UROP) spawned an undergraduate research program at another institution. Again inquiries have set similar ideas in motion elsewhere. Alumni interest kept busy even more undergraduate speakers than in past years. Student participation in UROP was at a higher level than last year. Faculty support of student research reached a record dollar amount. Nonetheless, the severe financial constraints of recent years are still with us: our budget remains insufficient during this year, and sorely needed storage and conference space remains unassigned.

Since 1973 MIT's financial commitment to UROP via General Funds has been approximately $375,000. Seen within the framework of the nation's dramatic economic change evident in the latter years of our 15 year history, this ever eroding-in-buying power budget from General Funds has placed us in a difficult situation as we look ahead to the coming academic year. We have steadily run office operations with a small staff and lean style. Despite this, inflation has run far ahead of our ability to serve students and faculty with UROP funds. UROP's General Funds-supported student wage rate has been out of line with the Institute's minimum student wage rate since 1982 when the latter rose to $4.90 an hour. From 1969 until 1982, UROP's wage rate equaled or surpassed the Institute-wide wage. However, since 1982, UROP has not been able to keep up. The current Institute minimum wage is $5.50 an hour; with great squeezing UROP will manage to offer $5.25 this fall. We oppose the linkage of regularly increasing tuition costs to yearly minimum wage rate increases (an issue discussed this spring and last in the Student Wage Review Committee). Ever increasing Institute minimum wage thresholds are ultimately self-defeating. Without more General Funds, UROP is left to decide between a two-tiered student minimum wage or serving fewer students with the same budget. Even with the small increase of General Funds ($20,000) received for academic year 1985-1986, UROP will remain below the Institute minimum student wage next year. We continue to urge faculty to pay the Institute minimum student wage, or above when possible, in cases where students are paid wholly from faculty funds, even though we cannot afford this rate from our own General Funds allocation. Faculty cooperation on this issue has continued to be quite generous. Without this steady and enlarging pool of faculty-contributed research support to undergraduates we could not have maintained the high level of student access to UROP. We believe that the recent retreats from supporting UROP from General Funds at a level indexed to wage increases elsewhere at MIT is now resulting in curtailed participation in research by undergraduates with large personal need and by undergraduate desire to work in research areas not strongly supported by sponsored research sources.

Student participation this year was somewhat higher than last. Those seeking to become involved in UROP for pay comprised 57 percent of total UROPers during this past year, evidence of an apparent shift from credit toward pay. We have waived overhead and employee benefits during this academic year on 29 percent more in student wages than in the previous (1983-1984) academic year, approaching the $1 million mark for the first time in academic year figures alone. Summer of 1985 will undoubtedly bring us beyond the $2 million mark on overhead waived student wages. This steep rate of increase has been in play since 1974, 1973 having been the first year overhead was waived on student wages.

With initial funding of $70,000 for the program and envisioned support in the first quarter for some 70 undergraduates, the University of Minnesota officially launched its UROP program this spring following extensive consultation with MIT UROP. Their program's first directory of faculty research--modeled on the MIT UROP Directory--was published, and their hopes are high for growth over the next year. At Stanford University, where several attempts have already been made to have an MIT-style undergraduate research program, a new effort is presently underway as part of their major fundraising campaign. The University of California at Los Angeles is currently making a major effort as well toward implementing an undergraduate research program based on the MIT model. Their first directory is to be issued in July 1985. Brown University continued its association with UROP this year by inviting us to offer a workshop at the Conference on Collaboration in Undergraduate Education, sponsored by the Fund for the Improvement of Post-Secondary Education, by the Association of American Colleges and SUNY-Oswego, and held at Brown in September 1984. Interest in UROP has also been expressed by Lehigh University, the University of California at Santa Barbara, the University of Chicago, and others. UROP information is once again on its way to the People's Republic of China.

A source of pride for UROP this year was our invitation from corporation chairman David Saxon to assemble a group of UROPers to meet with Dr. Edwin H. Land, founder and past president of Polaroid Corporation, now director of the Rowland Institute for Science. It was Dr. Land's lecture "A Generation of Greatness" which had prepared the ground and inspired those who midwifed UROP's beginnings. The meeting this spring with
students was an occasion selected by Dr. Land as the connection with MIT he most desired. Participating students and alumni were: Jeff Abrahamson, Class of 1987; Jonathan Cohen, Class of 1983; Keith Daly, Class of 1985; Marc Fileman, Class of 1988; Anita Killian, Class of 1985; Anne Ko, Class of 1983; Anjali Sastry, Class of 1986; and Michael Scardera, Class of 1985. Another group of UROP students met this spring with New England Life Insurance Company president John A. Fibiger and vice president James A. Gallaher. The success of these undergraduate "round tables" with major business figures was such that we see here an opportunity for increased UROP activity. These meetings have by necessity been held in rooms other than UROP office space. Storage has long since pre-empted much of our already small office space. We await assignment of additional space in an adjacent corridor of building 20.

New England Life Insurance Company is one of the financial resources which help UROP reward and support outstanding research work. This year New England Life awards went to eight students working on health-related issues. We are in the third year of a four year grant from New England Life. We were also aided by funds from the Class of 1970 through awards given to three students involved in socially oriented research. Since its conception in 1972 this fund has provided almost $18,000 of stipend support to 39 students. In conjunction with the class' fifteenth reunion UROP is seeking replenishment of funds which will be depleted by year's end. The Class of 1972 awarded support to three students for research which helped "improve the quality of life through its impact on society and/or the environment." James McCormack awards supported seven students. This fund, established in memory of General James McCormack, Class of 1977, to support undergraduate research in areas relating to technology and its applications to the problems of mankind, society and the arts, will expire at year's end. Renewal will be sought. The Society for Sigma Xi helped five students with support for materials or travel. One of the winners, Dinh Le, Class of 1986, was also the recipient of the Joel M. Orloff Award for outstanding ability and creativity in physics-related research. Adam Cohen, Class of 1985, another Sigma Xi recipient, also won an Eloranta Summer Research Fellowship.

Eloranta Fellowships, gifts from Dr. Land, provide $4,000 to several students planning and carrying out their own research ideas during the summer months. There were four other Eloranta Fellowship recipients for the summer of 1985: Brenda Golianu, Class of 1985; Raymond Meilunas, Class of 1986; Richard R. Maurer, Class of 1986; and Dmitry Zarkh, Class of 1986. The Department of Civil Engineering provided support for eight freshmen to encourage undergraduate research in that field through UROP traineeship awards. One honorary traineeship was awarded to a sophomore. The Department of Nuclear Engineering has similar UROP support planned for the next academic year. Sea Grant supported nine undergraduates in the fall and eight in the spring term. Two awards were given for achievement in original engineering design by the Clapp and Poliak Engineering Design Awards committee. Gifts to this fund ceased a year ago and the committee is actively seeking future research support from potential donors. Support came this year also from Wellesley College which supported an MIT biology student working on biology research with a Wellesley faculty member.

Support for undergraduate research came in the form of donations to UROP from alumni UROPers. There were also invitations from 5 MIT alumni clubs across the country. The spring speaking schedule was full with two students addressing the Greensboro, North Carolina alumni club, Werner Brooks, Class of 1986, and Randy Schweickart, Class of 1984, (a graduate student at nearby Duke University in Chapel Hill); Robert Joy, Class of 1987, and Anne LaVin, Class of 1985, at New Haven, Connecticut; Keith Daly, Class of 1985, and Anita Killian, Class of 1985, (both participants as well in the "round table" with Dr. Land) at Springfield, Massachusetts; Brian Fufes, Class of 1984, and Sossina Halle, Class of 1987, at the Minneapolis alumni club, (both students Minnesotans); and two UROPers, Carol Mitze, Class of 1985, and Jeffrey Munic, Class of 1985, visiting the Portland, Maine alumni club. Invitations to Portland, Minnesota, and Greensboro were firsts. The visit to New Haven was the fourth for UROP. These meetings were well attended by newly admitted undergraduates in the process of making decisions about which college to attend. With increasing frequency we hear how these decisions are based on opportunities for undergraduate research at MIT.

UROP was also invited to participate in a fall meeting of high school guidance counselors visiting colleges in the Boston area. Four UROP students described their experiences to a group visiting MIT following a Boston-held national conference of college admissions counselors. In the spring UROP students and faculty hosted tours for newly admitted women of the Space Systems Laboratory and the new Center for Arts and Media Technology.

Other UROP activities were held during IAP, each activity offered for the third January. Michelle Lamarre held an information meeting for beginning UROPers deriving with the help of several active UROP students, how to find one's niche in undergraduate research. Norma McGavern held a briefing session concerning application for Eloranta Research Fellowships. It was well attended and probably was at least partly responsible for the healthy number of submissions by the April 1st Eloranta proposal deadline. Ms. McGavern also held a workshop on "Making Oral Presentations," an outgrowth of the undergraduate seminar that was given in the fall of 1984. Student interest makes it likely that this seminar will be given again in the fall of 1985. Plans are underway together with the Undergraduate Academic Support Office and the student Speech and Debate Society for an IAP oral presentation contest. UROP activities in oral presentations are supported by a small grant from the Raymond Stevens Fund.
Last year we took our first careful step into office computerization. This year computerization of UROP
data and office procedures has advanced to the stage where we can now efficiently track students currently
involved in UROP, print lists of selected information on a weekly basis for departments and laboratories,
and compile end-of-term statistics about participation and finances. Other programs for office operations
are being planned. We are, in fact, at a point where we are ready to upgrade our equipment, and are look-
ing forward to a time when an interoffice computer network system at MIT will allow us to link up with other
offices. Our rapid development of a good working office computer system is due to the effort and ingenuity
of Jae Sang, Class of 1988, who visited the UROP office one day to volunteer help on a computing problem
and ended up writing our programs.

UROP director Margaret MacVicar was appointed to the newly created post of dean for undergraduate education
this spring, as part of the undergraduate educational initiative announced by new provost John M. Deutch.
This change will be effective July 1, 1985. Professor MacVicar served also as vice president of the Carnegie
Institution of Washington, D. C. for the second year. Day-to-day operations were overseen by Ms. McGavern,
associate director. Ms. Lamarre continued as assistant director. Our restructuring of last year proved
successful with Maureen Horgan and Lisa Merritt completing their first years as half-time staff administra-
tive assistant and full-time staff assistant, respectively. Gregory Smith, as special projects coordinator,
has made enormous numbers of site visits to UROP students, in addition to his activities on behalf of the
Council for the Arts. Student workers have added their lively presence to our office on a part-time basis.

MARGARET L.A. MACVICAR
NORMA G. MCGAVERN
Upward Bound Program

The MIT/ Wellesley Upward Bound Program is a coeducational, multiracial educational program for Cambridge high-school youth. Now in its eighteenth year, the Program services 70 academically promising young men and women from disadvantaged backgrounds. The goal of the Program is to motivate these youths to attend college, and to provide them with the necessary skills needed 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, 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 promise in the youngsters. The staff, together with teachers and fellow students, play a crucial role, because what students think they can do is dependent on what others think they can do. The students' perceptions of their abilities, and therefore what they will try to accomplish, are thus to a large extent determined by the staff.

Summer Program

The summer program, conducted in residence on the Wellesley College campus for six weeks, 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, undergraduate and graduate, students from local colleges and universities, and Upward Bound alumni now attending college. Upward Bound students carry three classes, each of which meets for an average of 60 minutes per day, during the six-week summer program. Each student is required to take a mathematics and an English course and one science elective. Science courses include biology, physics, human physiology, computers, and chemistry. The mathematics program includes an enrichment section for students who have done poorly in algebra I, II, geometry, trigonometry, and pre-calculus and calculus courses for students who will be attending college in the fall.

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 over 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 in Cambridge. To achieve this, the following programs, staffed primarily by MIT or Wellesley College undergraduates, have been developed and implemented:

Study Skills. The MIT Upward Bound offices are open for study four days a week Mondays & Wednesdays from 3 to 6 P.M. and Tuesdays and Thursdays 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 agreed that the individual tutorials are no longer necessary (usually indicated by improvement of grades). Organization and time management are stressed, as well as effective negotiation techniques.

College Report, Class of 1985

Graduating seniors have been placed in colleges as follows: Northeastern University (4), Wheelock College, University of Massachusetts at Amherst (2), Hampton University, Clarke University, University of Alabama, Southeastern Massachusetts University (2) North Carolina Central University, Wentworth Institute, University of Lowell, Roxbury Community College, Massachusetts College of Art, Bloomfield College, Boston College (2).

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.

RONALD S. CRICHLOW
Interdisciplinary collaboration among faculty from the various MIT schools continues to provide a focus for our research and educational programs in the medical/biological field. This year, I am pleased to report on the following events and highlights.

Program in Biological and Medical Imaging

Interest is rapidly growing at MIT in the area of biological and medical imaging. Biological imaging includes the use of conventional and scanning electron microscopy to observe cellular and subcellular structures. The Laboratory for Computer-Assisted Microscopy and Medical Image Technology (formerly the Laboratory of Electron Microscopy) is directed by Dr. Alan Nelson who is an Assistant Professor in the Department of Nuclear Engineering and the Whitaker College. The laboratory was renamed to reflect its unique focus and research effort combining computer-based technology with electron microscope techniques for image and data enhancement and evaluation. Under the daily management of Dr. Roy L. Hughes, over sixty investigators are currently utilizing the facilities according to their individual requirements. Projects include studies of cultured cells, tumor metastasis experiments, and investigations of cytoskeletal elements in invertebrate larvae. Other projects are concerned with ceramic and metal materials, drug release polymers, and neurobiological studies. The laboratory is extensively involved in the development of techniques for microtomography and 3-dimensional reconstruction of images derived from NMR, PET, CT, and EM sources. Laboratory personnel also cooperate with investigators from other institutions with compatible interests in the area of equipment and techniques development.

Interest in medical imaging has centered largely on the relatively recent development of magnetic resonance imaging and positron tomography. Studies have been carried out using MR instruments at the Massachusetts General Hospital, and plans have now been made for an instrument to be located in the National Magnet Laboratory and to be administered and operated jointly by the Whitaker College and the Magnet Laboratory in collaboration with several area medical research groups. This imaging method promises to provide unique and useful information on various diseases. Much of the interest to date has centered on diseases of the brain. Professor Gordon L. Brownell, who has a primary appointment in the Department of Nuclear Engineering, has been extensively involved in studies on PT imaging which are carried out at the Physics Research Laboratory of the Massachusetts General Hospital and in the College's microscopy facility.

Academically, the biological and medical imaging program is tied to a doctoral program in Radiological Sciences. Funded by a NIH training grant to the College which provides tuition and stipend support for six students, doctoral candidates are admitted to the Department of Nuclear Engineering. It is anticipated that a total of eighteen students will be matriculating in the program next year. Professors Brownell and Nelson comprise the faculty.

Program in Medicinal Chemistry and Controlled Drug Delivery System

Research in Dr. Robert Langer's laboratory has led to the development of several new types of polymeric drug delivery systems. One such system has been particularly useful for delivering polypeptides. In addition, several novel biodegradable polymers have been synthesized from naturally occurring substances in the body, such as amino acids and fatty acids, and studied as new biomaterials and as components of new drug delivery systems. Methods of augmenting drug delivery on demand have also been developed which provide new hope for delivering drugs like insulin where increased levels are needed near mealtime. Two approaches, the use of magnetism and the use of ultrasound, both of which can be applied externally using watch-like devices, have been explored to address this problem. A significant achievement this year is the use of immobilized enzymes as a new way of using biomedical engineering to treat conditions leading to brain disease. Specifically, a new treatment has been developed which has been successfully employed in animals to treat neonatal jaundice - a leading cause of cerebral palsy and mental retardation. Professor Langer holds the Dorothy Poitras Chair in Medical Engineering in the Whitaker College. His primary appointment is in the Department of Applied Biological Sciences.

Programs in Human Biology

Dr. Monty Krieger, Assistant Professor in the Whitaker College and the Department of Biology, continues his outstanding work in the study of receptor-mediated endocytosis with particular reference to the operation of this mechanism in the metabolism of lipoproteins and their relationship to atherosclerosis.

Professor Robert Rosenberg, also holds an appointment in the Department of Biology and the Whitaker College, as well as the Beth Israel Hospital and the Harvard Medical School. The work of his laboratory is devoted to the elucidation of a variety of molecular interactions which regulate the coagulation system.
and maintain vessel wall function.

Program in Neurosciences

The development of a first-rate program in the neurosciences is proceeding very well on several fronts. The program is basically comprised of two complementary lines of research: systems neuroscience and neurobiology. The search for new faculty in both areas has been ongoing throughout the year and it is anticipated that at least two appointments, one in each area, will be made by the end of 1985.

Systems neuroscience at MIT is concerned primarily with sensory and motor systems and is strongly interdisciplinary. Professor Nelson Kiang is conducting research in auditory physiology with colleagues in the Department of Electrical Engineering and Computer Science and the Research Laboratory of Electronics at the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary. The research activity of this group encompasses auditory physiology, auditory psychophysics, and speech understanding and production. Dr. Kiang, who serves as Director of the Eaton-Peabody Laboratory, has an appointment in the Whitaker College, joint with the Department of Psychology and the Harvard Medical School.

The Center for Biological Information Processing, under the direction of Professor Tomaso Poggio and Dr. Ellen C. Hildreth, provides a focal point for collaboration among researchers in Artificial Intelligence, Engineering, Psychology and Neuroscience, with the goal of fostering an interdisciplinary approach to the study of information processing in the brain. Research at the Center currently focuses on the computations underlying the problems of vision and motor control, and the implementation of these computations in neural hardware. Activities at the Center began this winter, after the completion of the facilities which include office space, a Selspot laboratory for performing experiments in human motor control, and a laboratory for conducting experiments in visual psychophysics. In addition to the research collaboration at MIT, members of the Center also interact with experimentalists at the University of Alabama, the State University of New York at Stony Brook, Harvard, Waterloo University, McGill University, the University of Cambridge, and the National Institutes of Health.

The Center also promotes interdisciplinary interactions through seminars and courses. In June, a two-week lecture course in Computational Neuroscience, sponsored by the Sloan Foundation, was held at Cold Spring Harbor Laboratory in New York. Organized by myself, Chris Atkeson (a Psychology graduate student), Dr. Ellen Hildreth, and Professor J. Anthony Movshon of New York University, the aim of the course was to introduce students to computational approaches to the study of vision and motor control, and to show how computational and experimental approaches together can lead to an understanding of information processing in the brain. The course was attended by 22 top students from all over the world, with backgrounds ranging from neurobiology to physics and mathematics. It provided a unique opportunity to foster the type of interdisciplinary research in the brain sciences in which MIT is becoming a dominant leader.

A proposal for the creation of a program in Computational Approaches to the Brain Sciences has been generously funded beginning next year by the Sherman Fairchild Foundation.

In neurobiology, Dr. William G. Quinn and Dr. Ronald McKay were appointed to the faculty, effective July 1, 1984. Both appointments are joint with the Department of Biology. Dr. Quinn, Associate Professor, is exploring the mechanisms underlying learning and short-term memory in Drosophila by isolating single gene mutations and characterizing their effect on a variety of learned behaviors. He has discovered that several mutants affect the metabolism of cyclic AMP. This relationship, which has been researched by others using different approaches and another invertebrate species, suggests that changes in cyclic AMP levels in specific neurons may figure importantly in a broad range of learned responses in a variety of animal species, at least invertebrate ones. Dr. McKay, who is also an Associate Professor, is a neurobiologist with a strong background in molecular neurobiology. Using the tools of recombinant DNA technology, his research involves the identification and characterization of molecules involved in neuronal function and development.

To support our endeavors in neurobiology, the College has received funds from the Pew Memorial Trust Foundation, specifically for faculty and curriculum development.

The design of a new doctoral program in the Neurosciences, with systems neuroscience and neurobiology as the two main areas of specialization, is now underway for submission and approval in the near future.

Program in Health Policy/Management

The third class of four highly qualified students was admitted to the Program in Health Policy and Management, the only Ph.D. program of this kind in the country designed specifically for physicians and medical students. Under the directorship of Professor 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. Support for students is provided from funds granted to MIT by the Henry J. Kaiser Foundation.

In April, the program hosted a national meeting entitled "Symposium on Medical Decision Making and Health Policy" in conjunction with the Institute of Management Science and the Operations Research Society of America.

Other Activities

The Whitaker College Computer Facility, under the management of Dr. William Gilbert, currently bills over 120 active accounts on a monthly basis for services on the DEC VAX 11/780. In addition to state-of-the-art computational and graphics hardware, the Facility offers a wealth of end user software including the RS/1 database management package, MINITAB and SAS statistical packages and MASS-11 scientific word processing. The Facility was the subject of a recent article published by Microsystems Engineering Corporation for its MASS-11 user base. The Facility has also collected and organized a series of programs for assisting the molecular biologist in DNA and protein sequence analysis. These programs are used by MIT's Biology and Chemistry Departments, the Center for Cancer Research, the Whitehead Institute and faculty members from Tufts University and Wellesley College.

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 last year. As in the past, the lectures and receptions that followed were very well attended by the institute community.

A Neuroscience seminar luncheon series, which consisted of both invited and in-house speakers as well as general discussions, was held throughout the academic year to promote exchange and exposure to the latest developments in the field. The seminars were held three to four times a week and were extremely successful in establishing a sense of community among the various disciplines. The luncheon series will resume in September.

Five pre-doctoral fellowships were again 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 and Edward J. Poitras Fellowship funds.

Faculty and Staff

Effective July 1, 1984, Dr. William G. Quinn was appointed Associate Professor of Neurobiology. This year Dr. Quinn was named a recipient of the prestigious McKnight Award for Neuroscience Development.

Dr. Ronald D. McKay was also appointed on July 1, 1984. Dr. McKay is an Associate Professor of Neurobiology and holds the Edward J. Poitras Chair in Human Biology and Experimental Medicine.

Dr. Monty Krieger, who teaches both undergraduate and graduate courses in the Department of Biology, received this year's School of Science Award for excellence in Undergraduate Teaching. He also received the Graduate Student Council Prize for Teaching in Biology.

Dr. Roy L. Hughes was appointed Manager of the Laboratory for Computer-Assisted Microscopy and Medical Imaging Technology in October, 1984.

Joint appointments to the College include: Dr. Ann M. Graybiel, Professor of Neuroanatomy, Dr. Peter H. Schiller, Professor of Neuroscience, Dr. Gerald E. Schneider, Professor of Neuroscience - all joint with the Department of Psychology; Dr. Tomaso A. Poggio, Professor of Vision Science and Biophysics and Dr. John M. Hollerbach, Assistant Professor - joint with the Department of Psychology and the Artificial Intelligence Laboratory; Dr. Richard J. Wurtman, Professor of Neuropharmacology and Dr. R. Alan North, Professor of Neuropharmacology - joint with the Department of Applied Biological Sciences; and Dr. Gordon L. Brownell, Professor of Nuclear Engineering - joint with the Department of Nuclear Engineering.

EMILIO BIZZI
Chairman of the Faculty

The Committee on Educational Policy (CEP) and the other Faculty committees addressed a number of significant issues during the past year. These activities are highlighted in the following report.

Imbalance in Undergraduate Enrollment among Departments

The CEP's intensive effort to address the enrollment imbalance problem (described in detail in last year's report) was concluded early in the fall. A report for the May 1984 Faculty Meeting had discussed the potential damage to the Department of Electrical Engineering and Computer Science and its programs if steps were not taken to substantially reduce the number of EECS undergraduate majors from current levels. That report also concluded that if the noncoercive efforts being undertaken did not result in a sufficient decline in EECS enrollment, overt restrictions might be unavoidable. The Faculty affirmed that: a) if restrictions are to be applied, they should be applied during the admissions process and communicated to students before they accept admission to MIT, and b) the CEP should present at the September 1984 Faculty Meeting a detailed contingency plan along these lines which makes the least perturbation in the admissions process and on external perceptions of MIT.

The proposed course of action that was presented in September and subsequently approved at the October Faculty Meeting was developed by a CEP subgroup (A. Smith, chair, E. Devereux, B. Kellermann, K. Manning, P. Richardson, D. Wiley, and S. Widnall) in consultation with various faculty, students, and staff. The contingency plan established specific goals for the reduction in Course 6 enrollments over the next several years and procedures for deciding whether to implement a process which would restrict the option of some admitted students to major in Course 6.

Responsibility for implementation of restricted admissions, if such a step becomes necessary, is assigned to the Director of Admissions under the guidance of the Committee on Undergraduate Admissions and Financial Aid (CUAFA) and in accordance with several specific general principles: 1) The overall objective, while reducing the number of undergraduate EECS majors, would be to get the best class possible with a broad range of interests and backgrounds into MIT, and to ensure that students receiving restricted admission would be distributed throughout the admissions matrix. 2) Admissions decisions would be made independently of the designation of those who would receive restricted admission. 3) Information on career interests, based on the entire admissions application, may be used in the process of designating restrictions.

The way in which MIT deals with enrollment imbalance can have important consequences for the Institute and its students. Many of these consequences are hard to predict, and continuing care is needed to avoid actions which would be regarded as unacceptable. Because sufficient progress had been made in reducing Course 6 sophomore enrollments, CUAFA decided in October, under the authority granted to them by the Faculty, not to impose admissions restrictions on the freshman class entering MIT in 1985. During the year, continued efforts were made to ensure that freshmen received various kinds of information which would acquaint them with the wide variety of departmental program opportunities at MIT.

The CEP reviewed two new departmental program options, Mathematics with Computer Science and Physics with Electrical Engineering, which, apart from the substantive intellectual rationale for their creation, are expected to help address the enrollment imbalance. The projected enrollment of sophomores in Course 6 for next fall showed sufficient further decline that CUAFA decided in May not to impose enrollment restrictions on the freshman class entering MIT in fall 1986.

Structure of the Undergraduate Program

As described in last year's report, the CEP has been concerned for several years with the goals, content, and structure of the undergraduate program. The issues center on the need to reconcile, in a four-year curriculum, MIT's dual goals of providing a reasonable level of literacy in science and humanities and giving appropriate professional specialization.

Undergraduate academic officers were asked for their views on some issues in undergraduate education, and the concerns raised in the responses reinforced the CEP's view that there were some important matters that needed to be pursued. The CEP decided to focus on the structure of the undergraduate program and to clarify the language in Faculty Regulation 2.82 specifying this structure.

A CEP subgroup (A. Smith, chair, C. Canizares, H. Ritvo, L. Silverman, R. Wagner, D. Wiley, N. Wilson, M. Wrighton, and B. Wuenisch) was formed to consider the structure of the undergraduate program. A study was undertaken of the transcripts of a sample of last year's graduating seniors to obtain data on the content and structure of their degree programs.
The proposals that emerged to address the structure of the undergraduate degree requirements do not change the character of an MIT education, but specify its parts in a way that more clearly reflects the overall educational experience that is desirable for our students. The proposals clarify the statement of the S.B. degree specifications (the language had become unwieldy and no longer consistent with current circumstances), use both units and subjects as appropriate measures of degree programs (recognizing that neither are totally satisfactory measures), and define the balance between general education and departmental professional requirements.

The specific proposals limit the size of departmental programs, require that departmental programs make it possible for students to complete all S.B. degree requirements in the equivalent of 32 to 34 subjects, implicitly remove the constraint that most HASS subjects be nine units (placing all parts of MIT on a similar accounting system), guarantee a minimum of unrestricted elective units in students' programs, require that students take a Science Distribution subject outside of their departmental program, make guidelines for Laboratory subjects more consistent with current practice, state the General Institute Requirements as a requirement of 17 subjects (rather than as a number of units) with the same content as before, and specify the minimum work students must do at MIT for their S.B. degree.

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The issues addressed by the proposals have important Institute-wide ramifications. It was felt that articulating the various parts of the undergraduate degree requirements more clearly at this time should provide a framework to help facilitate substantive discussions of content that are beginning to take place. The proposals were adopted by the Faculty at the 15 May 1985 Faculty Meeting and will become effective with the class entering MIT in fall 1986.

Reorganization of the Faculty Committee Structure

During the year, the CEP had discussions on the organization of the central administration and the Faculty committee structure, with the goal of improving oversight and development of undergraduate education at MIT. Based on the work of a CEP subcommittee (R. Whitman, chair, E. Devereux, L. Gould, and R. Jaffe), the CEP reviewed a number of relevant issues, including the charter of the CEP and the manner in which the CEP is able to function.

The basic conclusion was that the CEP has been expected to take on a broader range of tasks than a single Faculty committee can effectively undertake: to serve both as the senior standing committee of the Faculty (coordinating the policy-related activities of other standing committees) and as the primary Faculty committee concerned with undergraduate education (developing and implementing educational policy and overseeing educational experiments). The CEP's broad range of responsibilities, the absence of someone in the administration with specific responsibility for the undergraduate program, the need to address short-term policy questions, the burden of weekly meetings and other assignments, and the lack of continuity from the two-year terms of CEP members have combined to make it particularly difficult for the CEP to undertake the sustained efforts that are needed to examine fundamental, long-range issues relating to the direction of an MIT undergraduate education.

The subcommittee recommended establishing an administrative office specifically responsible for the undergraduate program and making a revision in the Faculty committee structure to support that office. Provost-designate John Deutch also recognized the need for a change in the administrative structure and appointed a Dean for Undergraduate Education as part of his initiative to place greater emphasis on the undergraduate program.

The CEP proposed to the Faculty that the CEP's present responsibilities should be broadened and divided between two Faculty committees: The Faculty Policy Committee (FPC), chaired by the Chairman of the Faculty, would have responsibility, as the senior Faculty committee, to maintain a broad overview of MIT's academic programs; to interpret, implement, and help formulate policy on a broad range of issues of concern to the Faculty; to coordinate the work of the other Faculty committees; and to enhance faculty/administration interchange. The Committee on the Undergraduate Program (CUP), chaired by the Dean for Undergraduate Education, would have responsibility in undergraduate education to encourage experimental innovation; interpret and implement policy; approve and supervise limited experiments; and exercise general oversight of the undergraduate program, including the freshman year and other interdepartmental programs, with particular attention to long-term directions. This proposal was approved by the Faculty in May and the two new Faculty committees will begin operation in the fall.

The new structure alters the term of the Chairman of the Faculty to one year as Chairman-elect followed by two years as Chairman; makes the terms of all standing committee members elected by the Faculty three years, in order to provide for greater continuity; and establishes different liaison relationships among the Faculty committees and between the committees and the administration.
Freshman Internal Grades

In fall 1982, the Faculty approved an educational experiment whereby freshmen receive informal internal grades in their subjects at the end of the spring term for the purpose of self-evaluation and internal advising. The internal grades do not appear on either the official internal grade report or the transcript of the student. The educational experiment was undertaken in response to the relatively low number of freshman evaluation forms completed at the end of the spring term (about half) and to the concern that sophomore advisors frequently had little useful information from that term on their advisees.

During the winter, a CEP subcommittee (A. Smith, chair, H. Heine, M. Richardson, and D. Wiley) undertook several tasks to evaluate the effectiveness of the internal grade system. These included a survey of undergraduate academic officers and individual sophomore advisors (the vast majority of whom saw the internal grade information as helpful and supported the provision of internal grades at the end of the spring term), small group discussions with sophomores, and meetings with administrative assistants and academic officers in the departments that have the greatest dealings with internal grades. The findings suggested that the modifications in the freshman evaluation provisions put into place in 1982-83 are working well, and that concerns expressed then about internal grades -- that pressure and student anxiety would increase -- have proved unwarranted. It is clear, however, that both students and advisors must periodically be reminded of the restrictions on the use of internal grades.

The CEP reported to the Faculty in March, and the Faculty approved the proposal to make the provision for freshman internal grades in the spring term a permanent part of the Faculty Regulations.

Other CEP Actions

The Faculty approved a proposal from the Departments of Chemistry and Biology and the CEP to remove the subjects 7.01 and 5.60 as options for satisfying the General Institute core science requirements -- on the grounds that the subjects, which require basic chemistry as a prerequisite, were not realistic options for the overwhelming majority of our students. In preparation for reprinting the Rules and Regulations of the Faculty, the Faculty adopted a number of housekeeping changes proposed by the CEP, which included a provision to encourage the timely completion of subjects in which undergraduates had received an I grade (Incomplete).

The CEP also: had several discussions on humanities, arts, and social sciences education at MIT; formally established the Ad Hoc Catalogue Committee to operationally discharge, under the CEP's oversight, the CEP's responsibilities with respect to the catalogue; had several discussions on the role and future of the Course Evaluation Guide; discussed snow closing policy; and addressed progress reports from Project Athena, the Athena Study Group, the IAP Policy Committee (including results of the Faculty Survey), the Committee on the Writing Requirement, CUAPA, and the Integrated Studies Program.

Other Faculty Committee Reports

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year, excerpted as follows:

As usual, the Committee on Academic Performance (CAP) spent most of its time dealing with the difficult situations of the relatively few MIT undergraduates who are or might be in academic difficulty. Other concerns included the following: 1) Much of the CAP's business is due to inadequate advising, which is particularly reflected in the innumerable petitions to the CAP to change a student's registration status; the faculty advising system needs to be looked at. 2) The CAP circulated a letter to all undergraduate departments drawing attention to the fact that a grade of D points to serious inadequacies in the student's knowledge of his or her subject. Some departments do not act on this information; others insist on remedial action in some circumstances. This unevenness in dealing with a not uncommon problem may have to be addressed in the future. In this connection, the CAP is increasingly concerned that a small number of students are recommended by their department for a degree with a cum rating well below 3.0. 3) The CAP also circulated a letter to departmental undergraduate officers advising them of increasing reluctance by the CAP to approve a degree with a "single deficiency" if that deficiency exists in a subject which is an Institute requirement. 4) In an effort to alleviate last minute petitioning at the end of this past spring term, the Committee asked students with outstanding Incompletes on their record from the terms 84-1 and 84-2 to petition the Committee for extensions before their term of graduation. The response to this request was very good and did indeed reduce the number of late petitions.

The Committee on Curricula continued its traditional task of overseeing the undergraduate curriculum. There were fewer student petitions than in the past, reflecting either better rules or better student understanding of the rules. While specific issues were raised during the year in the process of approving Courses and subjects, they have been superseded by the rules revisions just approved by the Faculty. Mr. Ronald Smith, the Committee's executive officer, provided major support to the Committee.
The work of the Committee on Discipline consisted of adjudicating a number of specific grievances against students brought to the Committee's attention by members of the MIT community.

During the past academic year, the Committee on Student Affairs: 1) reinstituted the practice of having small working groups to assist each of the sections of the Office of the Dean for Student Affairs and, when appropriate, to bring items to the attention of the entire CSA, and 2) contributed to the formation and acceptance of an alcohol policy suitable to all segments of MIT. The CSA also discussed many aspects of student life, including the value to students and faculty of the SCEP course evaluation guide.

During the year the Committee on Undergraduate Admissions and Financial Aid: 1) undertook a major educational effort to become familiar with trends and issues in both the admissions and financial aid areas; the normal operating procedures in both areas have a number of policy matters imbedded within them that are important to understand; 2) decided not to impose admissions restrictions with respect to choice of major on the freshman classes entering MIT in fall 1985 and 1986; 3) considered the notion of diversity and the "shape of a class" -- how the class as a whole is put together and how MIT can take a more assertive role in that regard (which requires developing a more refined profile of each class); 4) assessed the need for a fundamental reexamination of the SI (Scholastic Index); 5) established admissions policy with respect to applicants having extraordinarily high academic credentials; 6) broadened the number and the role of faculty readers of admissions folders, including the reading of applications from minority students; 7) discussed minority recruitment and ways to increase the number of minority students at MIT, including the issue of differential self-help (a concerted effort is needed to understand the dramatic decline this year in the number of admitted minority students); 8) developed new policy in the area of outside scholarships, to provide greater incentives to students and to pay greater respect to the donors of outside scholarships; 9) examined the policies and procedures followed by the Financial Aid Office in determining the "parents' contribution," which can affect our competitiveness with other institutions; and 10) discussed transfer admission policy, with the goal of broadening it and coupling transfer admissions more closely with the departments.

The Committee on the Writing Requirement concentrated this year on implementing Phase Two of the Requirement, while continuing to monitor and report on Phase One. In order to inform students about Phase Two, which affects the Class of 1987 next fall, we have worked with the departments to draw up Phase Two guides relating Course work to the general options outlined within the Requirement. Fifteen departments have already written guides; the remaining departments should complete theirs soon. The Committee has also informed the larger MIT community about the Requirement, disseminating criteria to faculty members and holding meetings with them and administrative staff to review the progress of the Requirement. Our 18-member Board of Evaluators has been extremely useful in resolving occasional divergences of opinion and in defining the standards to be maintained in judging students' writing.

The Committee on Faculty-Administration considered the following issues during the past academic year: 1) sanctions for the misconduct of a tenured faculty member of the Institute, which also led to the study of a proposal to revise the section in Policies and Procedures on the termination of tenure; 2) MIT's policies in the wake of the removal of age 70 as the mandatory retirement requirement; 3) actions that could be taken by MIT regarding the possible tax liability on the payment for faculty and staff eligible for the children's scholarship benefit resulting from changes in the IRS regulations; and 4) the possibility of deviating from the seven-year-to-tenure rule in order to permit a period longer than seven years for the School of Humanities and Social Science as a whole, and/or for departments within that School or in other Schools.

The Committee on Industrial Liaison had an active year in addressing four key issues: 1) strategies for recruiting and retaining top-notch ILP professional staff, 2) possible geographical (international) and topical limits on the range of ILP member companies, 3) approaches to ensuring greater faculty involvement in the recruitment of ILP member companies, and 4) guidelines for the support of on-campus collegiums involving ILP member companies. In the course of addressing these topics, the Committee also recommended the creation of a graduate student ILP Intern Program for the Technology and Policy Program in the School of Engineering.

The Committee on the Library System reviewed a number of matters, including: the Libraries' activities in the areas of automation, space needs, and budget; confidentiality of circulation records in both the manual and automated systems; the Libraries' budget request for fiscal year 1988; and the role of the Libraries in Project Athena. The Committee reviewed and approved the allocation of acquisition funds in fiscal year 1985.

The Committee on Outside Professional Activities devoted most of its attention to investigating confidential matters pertaining to faculty conflict of interest and to advising faculty and administrative staff in this regard. Some minor revisions were made in relevant sections of Policies and Procedures.

The Committee on Nominations presented its slate of officers and elected members of the Faculty committees at the April Faculty meeting, and filled vacancies in the elected membership as needed during the year.
Professor Franco Modigliani was named the Killian Faculty Achievement Award Lecturer, and Professor Robert Berwick was the recipient of the Edgerton Faculty Achievement Award.

Subsequent to expressions of concern in a letter signed by a number of faculty members and discussion at the March Faculty Meeting, the Ad Hoc Committee on MIT's Military Involvement was established, which will advise the Faculty regarding changes in military funding and influence at MIT and the effects on the education of our students. A charge to the committee, which will be chaired by Professor Carl Kaysen, has been developed in consultation with the officers of the Faculty.

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: Vernon Ingram (Academic Performance), Peter Temin (Curricula), Elias Gyftopoulos (Discipline), Arnoldo Hax (Faculty-Administration), Lawrence Susskind (Industrial Liaison), Henry Marcus (Library System), Richard Cartwright (Nominations), Thomas Sheridan (Outside Professional Activities), Alvin Drake (Student Affairs), Kenneth Manning (Undergraduate Admissions and Financial Aid), Kenneth Hoffman (Writing Requirement), Suzanne Berger (Killian Award Selection Committee), and Pauline Maier (Edgerton Award Selection Committee).

The following completed their service on the CEP at the end of the 1984-85 academic year: Professors Arthur Smith, Chairman of the Faculty, Thomas Allen, Associate Chairman of the Faculty, Claude Canizares, Aaron Fleisher, Leonard Gould, Wesley Harris, Robert Jaffe, Kenneth Manning, Harriet Ritvo, Eric von Hippel, Robert Whitman, Nigel Wilson, Mark Wrighton, and Bernhardt Wuensch; student members Erik Devereux, Mark Fister, Steven Llorente, Joseph Romm, Lora Silverman, and Robin Wagner; and Francis Low, Provost; Frank Perkins, Associate Provost; Constantine Simonides, Vice President; Shirley McBay, Dean for Student Affairs; and David Wiley, Executive Officer. Their contributions are greatly appreciated. Professors Allen, Whitman, and Wrighton, Mr. Simonides, and Dean McBay will continue as members of one or the other of the two new Faculty committees.

ARTHUR C. SMITH
DAVID S. WILEY
School of Architecture and Planning

The School is implementing, under the guidance of the Dean and the School Council, a medium range plan that includes initiatives, and their priority, as well as projections about reductions and redirection. These plans were developed through processes that are responsive to the aims and directions of faculty and programs. The plans must also respond to the continuing financial constraints facing the Institute as a whole.

Our objectives in these plans are grouped around several core areas: quality of education and research; quality of the School’s physical environment; financial support for students; composition of the community of faculty and students; and connections to alumni and professional practice.

Quality of Education and Research

Steady progress is being made in the ongoing revision of the Master of Architecture program. Major funding received by the Aga Khan Program for Islamic Architecture will support development of a master’s degree specialization in design for Islamic cultures and collaboration with parallel programs and institutions in the Islamic world. The interdisciplinary media arts and sciences group, which now offers a Master of Science in Visual Studies program, begins the second year experiment in developing a four-year program of doctoral studies in media technology.

The objective of reducing the size of the Ph.D. program in planning has been achieved, and the new option in developing areas for the Master of City Planning program has been successfully implemented. The first accrediting committee of the American Institute of Certified Planners judged that we provide the most outstanding city planning program in the country. The first class for the degree of Master of Science in Real Estate Development will graduate in October.

Across the School, we are now beginning the task of exploring new and more diverse forms of undergraduate education.

Quality of the School’s Physical Environment

Anticipated change was dramatized this past year by some major moving days. At once indicative of environmental improvement, the School’s physical changes also reflect our efforts to stay in the forefront of professional education.

In the fall, the Center for Real Estate Development occupied new quarters in W-31, which were designed by former Professor Eduardo Catalano. Shortly thereafter, the Media Laboratory brought together some 40 faculty and research staff in a new East Campus building designed by School alumnus I.M. Pei. The Hayden Gallery moved to the same facility to become part of the Albert and Vera List Center for the Visual Arts. This fall the new building will itself be officially dedicated as the Laya and Jerome Wiesner Building. As a result of the Media Lab move, our busy Computer Resource Lab, which directs the School’s Project Athena programs, was able to occupy permanent space on the fifth floor of Building 9.

As part of a School policy for expansion at the periphery of the campus, the commitment of funding by the Institute enables us to consolidate most parts of the SMArchS degree faculty and students on the fourth floor of N52 and to move departmental research activities and the Laboratory of Architecture and Planning to the third floor of N51. The completion of these moves in the coming year will bring together now scattered research activities under a single roof. Professor Shun Kanda serves as the design advisor to the client group guiding the renovation of N51 and the adjoining N52.

Concomitant with peripheral growth we have planned for improvement of School space in the Institute's main building to establish a major center for School-wide intellectual and social events. Thanks to direct student effort in the Department of Architecture, initial steps on a modest scale were taken this past year, and the School now enjoys a new coffee shop on the fourth floor of Building 7 as well as improved exhibit space in the adjoining corridor around the dome. In the coming year more permanent exhibit facilities will be constructed, which are compatible with an overall Center design prepared by Professor Jan Wampler.
Also at the Center, Professor Imre Halasz completed a feasible schematic design for the renovation and expansion of Rotch Library. The scheme envisions a lateral expansion in the courtyard behind Building 7 -- a "bookcase" addition designed to house new stacks and reading areas on three levels joined to the library's two floors by bridges across a connecting light well. Projected changes also call for enlarging and air conditioning Rotch Visual Collections, housed since 1975 in the Louis Skidmore Room designed by former Department of Architecture Head Donlyn Lyndon. The next task will be to secure the funding required to implement the Rotch plans.

Financial Support for Students

This past year the Institute made a major, but temporary, increment of support available to graduate students in the MArch and SMArchS programs. The Department of Architecture also redirected some of the funds from its academic programs to the mission of providing financial support for graduate students.

A School-wide decision was made to merge our fundraising activities, which include a major component for student support, into the forthcoming Institute campaign. On another front, the efforts to develop research funding that can support students have not yet yielded hoped-for results. We are nevertheless confident that development of real estate research and the reconfiguration of housing studies will increase the volume of research over the next few years. Important also in increasing exploratory activity is a special three-year development grant from the Provost to the Laboratory of Architecture and Planning.

Composition of Community of Faculty and Students

We continue to have an exceptionally strong presence of women in our student body, but we are disappointed that minority applications are falling off, a reflection, we think, of the rising cost of our education. Strong progress has been made in the recruitment of women to faculty positions; no progress, on the other hand, has been made in minority faculty appointments. Similarly, progress was made in increasing the presence of women in the category of other academic staff, but again finding qualified minority members has proved difficult.

Connections to Alumni and Professional Practice

Impressive progress was made this year in strengthening our relationships to alumni with visits by School officials to Chicago, Vancouver, Montreal, San Francisco, New York, and Texas. These contacts contribute to laying the groundwork for fundraising; they also represent important resources for student recruitment and placement and for the School's connections to professional practice. In the coming year we expect to continue our alumni visits and to support events of special interest to our alumni.

As part of improving communications between the School and its professional audiences, we now supplement our newsletter, PLAN, with a distribution of a monthly events calendar in the Boston area. We are preparing the first School-wide brochure since 1960. This fall, in addition to the public lectures emanating from the many divisions of the School, we will inaugurate a lecture series sponsored by the Dean's office. Through such School-wide efforts we hope to enhance outside perception of the variety and intellectual wealth of our School.

JOHN de MONCHAUX
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* Only includes those students registered in Course IV
** Non-degree
*** Special non-degree programs in the Department of Urban Studies and Planning: the Special Program for Urban and Regional Studies of Developing Countries (SPURS), begun in 1967; and the Community Fellows Program (CFP), established in 1971
### FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1983-1985

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*Effective Full Time*
The focus of this academic year has been on taking the necessary steps to put in place the Five Year Plan developed in the previous year at the Institute's request. This Department's five year objectives are embedded in those of the School of Architecture and Planning, and the plan was developed in concert with other elements represented in the School.

The purpose underlying the plan is to continue energetically to develop theory in a field significantly lacking it, to undertake with increased energy to share our views in a wider world of architectural education and practice, and to continue to provide training to enable our graduates to enter the world of practice.

Objectives more sharply focused in the plan are increased collaboration within and among programs, further development of the research tradition in the Department, increased engagement of academic programs with issues of current and future professional practice, and effective action on issues of gender and race within the Department.

Attention to the professional Master of Architecture (MArch) program has been foremost and the issue of diversity in design studio teaching has been a key element in actions taken. A committee of senior design faculty formed last year reported out to the Department with a program for achieving appropriate diversifications in our design teaching. The program was made Department policy through consultation with the tenured faculty and the proposal for augmented studio offerings and a search for two new design teachers was approved.

The Department's intention to strengthen teaching and research in Building Technology increasingly appears to have a unique potential when seen in its collaborative roles with Mechanical and Civil Engineering. However, an extensive search for a senior faculty member to head the Building Technology Group has identified only one acceptable candidate and needs redirection. The result of this search suggests that much more needs to be done in order to realize the potential opportunities in the field. Other initiatives in this area include: the focus of the Laboratory for Architecture and Planning on building technology research, the concentration of the group's faculty and students in new quarters in building N52 along with other Master of Science in Architecture (SMArchS) faculty and students, and the creation of a new Career Development Chair in building technology, made possible by a gift from George Macomber.

A number of new programs have become active this year. The Center for Real Estate Development, established last year in the School of Architecture and Planning by Architecture and the Department of Urban Studies and Planning (DUSP) in collaboration with Civil Engineering and the Sloan School admitted and began training its first class of Master's candidates in the 12 month program. The School Computer Resource Laboratory (CRL) established last year by Architecture and DUSP moved into permanent quarters this year on the 5th floor of building 9, taking over the space developed by the Architectural Machine Group. The CRL is an element of the Institute-wide Project Athena, and subjects offered in the Lab are drawing strong enrollment.

Increased activity will occur in design and planning for developing areas, an area of study to which the Department has a long-standing commitment. The addition of a new senior professor in Architecture and Design for Islamic Cultures through the Aga Khan Program and the proposal of a new concentration in Design for Islamic Cultures within the SMArchS Program expand the opportunity for work in the field. Finally, collaborative work between SMArchS Housing and Settlement faculty, Design for Islamic Cultures, and students in the new DUSP Master's Degree Program concentration in developing areas will begin in the next academic year.

The Department participated with the School Council in the development of a fundraising plan and the first steps toward addressing two critical and perennial areas of need: financial support for our graduate students and upgrading the School's inadequate and dilapidated space. The first priority space improvement is expansion of Rotch Library which needs to double its present area. A feasibility study for expansion of Rotch Library, prepared by Professor Imre Halasz, has been approved by the Institute and funding for construction is being actively sought. The Department is also working on the adaptation of N52 for occupancy by the Building Technology and Design for Islamic Cultures groups in the coming year.
Funding for financial support for MArch and SMArchS students was increased by one-third, effective AY 1985-86, through serious intervention by the Institute and the Department. The interim measure was taken to relieve the serious burden of debt on our current students, brought on by high tuition, low starting salaries for beginning architects, and the formerly inadequate level of student support in these programs. With new funding now in hand, it is proposed to cap student debt at $20-$25,000 based on a standard criterion for need and application of resources most heavily to students in the final terms of the programs. The intention is that the level of support be sustained and increased in future years through Department and Institute fundraising efforts, and through Department work opportunities and research assistantships. Increased support for our students is crucial to keep the Department competitive with other well supported schools of architecture and to insure that our students can afford to enter the world of practice.

Finally, it should be noted that the considerable energy and talent of Department students were turned to a number of tasks with positive results. A student forum was brought into being which reports both to the Head and the new MArch Committee. Their meetings have been highly useful in bringing forward concerns about student support, the inadequacy of the physical plant, aspects of the curriculum, and a student organized international symposium proposed for MIT in IAP 1986. Women in Architecture in its second year of activity organized a seminar on women in architecture, a guest lecture series, and a seminar on gender as a determinant in architectural form. Three MArch students, Richard Berg, James Brandt, and Daniel Ng, renovated the exhibit space of the 4th floor of building 7 in a temporary way, developed plans for a permanent exhibition space to be part of a future permanent School center and ran the first Department exhibition series in recent history. Students continued to publish the Department newsletter, Architext, and ran the Coffee House for the second year in a row. It is hoped that this attractive and popular public place for the School can be added to by the installation of the permanent exhibition space.

PROGRAMS

In 1984-85 the Department had a total of 306 regular students and 5 special students in its five degree programs. Enrollments in PhD (30), SMArchS (59), EMVS (44), and MArch (87) remained relatively stable and BSAD (71) reversed the downward trend of the last ten years. Of the total student population 31 percent are women, 4.5 percent are minority, and 32 percent are international. There were 617 applications for admission to the Department in the fall of 1985, with PhD applications increased due to the new Media Arts and Sciences concentration and a 14 percent drop in applications to the MArch program.

Master of Architecture (MArch)

The ratio of applications for admission to the professional (MArch) program to available places remains high 202/28. A drop, however, is noted from 280 applications two years previously and 235 last year. Of the 202, 58 were offered admission, of whom 31 have accepted or 53 percent acceptance, a figure below that of three and four years previous. We are currently studying the possible cause for this relatively low rate of acceptance. The MArch Admissions Committee was chaired by Leon Groisser with the active involvement of three members of the design faculty and six MArch students. The program continues to enroll a large number of women students, 37 percent in 84-85, one of the highest among accredited schools of architecture in the country. The trend for the Department preprofessional (BSAD) graduates to elect to study for professional degrees at other universities continued this year.

MArch curriculum reformulation continued this year in the work of several committees. The committee chaired by Professors Robert Slattery and Jan Wampler on diversity in studio teaching in its fall report to the tenured faculty proposed that greater diversity in studio teaching be brought about by present faculty adding workshop subjects to design curriculum, and by a search for two new faculty, one a senior, distinguished practitioner/teacher and the other tenure-track position at the assistant or associate level. A committee has been established to carry out these two searches, chaired jointly by Professors Halasz and Slattery.

A committee chaired by the Department Head convened the design faculty once a week to discuss ways of enriching and diversifying the studio learning experience. A committee chaired by Professor William Porter proposed a new required subject in the Visual Training of Architects to be put in place in AY 86-87. A new MArch concentration was opened in Real Estate Development for students who intend to become architects but wish to understand more of the development process in their training. The concentration is made up of five subjects offered in the new M.S. in Real Estate Development Program. It is thought that exposure to development theories will be a powerful tool for the future architect whose field is in rapid change and needs to understand it in those terms. The new subject in Professional Practice proposed in 83-84 will be offered in AY 85-86 by Michael Joroff, Director of the School's Laboratory of Architecture and Planning.

Two new subjects have been offered this year as part of an ongoing program in Computer-Aided Design (CAD). Professor Halasz and Mr. Frank Miller, with support from Project Athena and the CRL, taught workshops in CAD both terms for architectural design credit. Visiting Professor Patrick Purcell gave an introductory subject in CAD.
In the spring term, the Department installed a management system for the MArch program, the MArch Committee, composed of three faculty, three students, and chaired this spring by the Head. This has proven to be a useful tool for bringing about changes variably desired by faculty, students, and for upgrading the intellectual and social life of the program and the Department.

The student lecture series offered a slate of speakers including Camilio Vergara on our Urban Ruins and Revitalization, Lucien Kroll, Jordan Gruzen, Rijk Rietveld, Balkrishna Doshi, Andres Duany, and a number of Department faculty who made presentations of recent work.

Awards to graduating MArch students were as follows: The Stanley Karofsky Prize to Garrett Wohl, the Francis Ward Chandler Prize to Louise Hara, the William E. Chamberlain Prize to Colin Flavin and Samuel Izenstadt, the Alpha Ro Chi Medal to David Vaughan, the AIA Certificate of Merit to Matthew Longo, and the AIA Medal to Paul Lukez. Paul Lukez also was the recipient of the Marvin E. Goody Prize, offered Institute-wide for a proposed thesis in building arts. The $5,000 prize is funded by a gift to MIT from Joan E. Goody in the name of Marvin E. Goody (MArch, '51) and former member of the Department faculty.

Master of Science in Architectural Studies (SMArchS)

While the number of applications to the SMArchS program remained more or less the same as for 1983, a smaller number of students enrolled in 1984: 22 as opposed to 33 for 1983. (The number of applications for 1985 has risen again and we expect about 40 students to enroll in 1985.) Program Chairman this year was Professor Julian Beinart.

The major curriculum change has been the addition of a fifth area of study to the SMArchS degree program, Design for Islamic Cultures. The arrival of Professor Ronald Lewcock, Aga Khan Professor of Architecture and Design for Islamic Cultures, has enabled us to admit the first students (8) to this area of study. They will begin their studies at MIT in fall 1985.

Research projects in the program have continued to engage many students and faculty. In September 1984, a study jointly sponsored by the Aga Khan Program for Islamic Architecture and the Malaysian Institute of Architects, was undertaken for the Golden Triangle area of Kuala Lumpur. The work done at MIT, directed by Professors Beinart and Lewcock, will be presented as an exhibition in Malaysia and at a conference on high-intensity development in summer 1985. In March 1985, Professor Beinart was appointed by Mayor Teddy Kollek to the Jerusalem Committee, the international advisory group for the city. Professor Nabeel Hamdi and Research Associate Reinhard Goethert worked with a team of MIT students on proposals for low-income housing in Sri Lanka as part of their ongoing examination of housing policy in that country. During the year, Professors Waclaw Sadowiak, Eric Dluhosch, and Ranko Bon initiated a research project on the building industry in Egypt. Professor Bon has also been working on building performance and expert systems studies for the IBM Corporation. Professor Harvey Bryan has been coordinating curriculum development and research in architectural lighting on a $100,000 gift from the G.T.E. Sylvania Corporation.

Master of Science in Visual Studies (SMVS)

The Wiesner Building became available for occupancy by the member groups of the Media Laboratory during the spring academic term. The Architecture Machine Group vacated building 9 in January and February, and by the end of the term, the Visible Language Workshop and Film/Video Section had moved as well. The Spatial Imaging Group's move coincided roughly with the end of the academic term and during this period groups outside the Department started to move their operations. By June 1985, the largely homeless Learning Research Group headed by Professor Seymour Papert, the Advanced Television Research Program headed by Professor William Schreiber, and the Electronic Music Studio headed by Professor Barry Vercoe are all functioning in the new building. New activities such as the Communications Group, headed by Professor Jerome B. Wiesner, and the Entertainment Group, headed by Marvin Denicoff began full-scale work.

Since the academic programs associated with the Laboratory are intimately tied to the research activities, the actual move--both physically and operationally--had no small effect on the teaching, admissions, and development of the degree programs. In spite of expected short-term dislocations, the long awaited proximity of research and teaching activities has propelled development of the doctoral program and helped clarify the continuously evolving S.M. Visual Studies Program. This is most clearly evident in the admissions process, which occurred in a new environment with an expanded constituency and an eye to the future that was never as pressing and obvious as before. As a result, the admitted incoming class is broader in background and interest. Next year's students are joining a complete program rather than a set of coordinated yet distinct groups; their applications reflected this expectation and it was realized.
The current class is also developing educationally significant inter-group liaisons that reflect faculty commitment to the broader definition of the Laboratory. This is a valuable indicator of the constructive effect of the move on the student body. The curriculum is evolving synchronously. Cross-registration in courses is up resulting in cross-fertilization of ideas and expertise.

The presence of several new faculty members in the Laboratory has increased the opportunities for research and teaching and broadened the scope of work. Professor David Zeltzer has assumed responsibility for the graphics programming courses and heads the Animation Research Group. He has singlehandedly established MIT as a center of expertise in the field. Dr. Alan Kay has accepted appointment in the Media Laboratory as a Lecturer. His pre-eminence as the inventor of the personal computer has significantly advanced the program in the eyes of the world and provided an academic forum for the development of many of his ideas. A new subject jointly proposed by him and Professor Andrew Lippman on interface technology has generated such national interest that it may have to be taught with teleconferenced participants. Professor Arun Netravalli is primarily allied to the Advanced Television Research Program but has already contributed to the Laboratory’s graphics program and the electronic publishing activities that have grown out of the Architecture Machine Group. Visiting Professor William Higginson has taken responsibility for the Learning Research Group’s course offerings and other activities.

Eleven SMVS students graduated last year, supervised by five faculty members. Topics ranged from explorations of basic issues in electronic graphic design and filmmaking to the implementation of a simultaneous personal computer color printer and image scanner. The particular expertise of the graduates is becoming increasingly recognized in their field. As well as the value of the breadth of the program was underestimated in industry and most post-graduate research establishments. The opposite is now true. It is increasingly difficult to keep students in the program during summers and through graduation; industrial and research opportunities are increasingly attractive.

Twenty students were admitted to the S.M. Visual Studies program and six to the Media Arts and Sciences doctoral program. Incoming master’s candidates are predominately interdisciplinary and doctoral candidates are intentionally so. Expected enrollment will be 66, 15 of the candidates. All doctoral candidates will be supported by fellowships and research assistantships. We currently have one NSF fellow and one recipient of the new IBM interface technology graduate fellowship. The Media Laboratory is strenuously attempting to establish additional support of this kind.

The S.M. Visual Studies is undergoing a thorough re-examination of its goals and purposes and its appropriateness as a terminal degree in the face of a new PhD program. The PhD program itself has been documented for Departmental and CGSP review in the fall, in order for it to pass from an experimental to an official program.

PhD

PhD students totaled 30, 21 in residence, 9 non-resident, 19 in History, Theory, and Criticism (HTC), 8 in Media Arts and Science (MAS), and 3 in special programs. Thirty three applications for admission were made to HTC with seven offerings of admission. Thirty seven applications for admission were made to MAS with six offerings of admission.

Professor Stanford Anderson chaired the Department PhD Committee with Professor Papert serving as head of the MAS subgroup.

A thorough search for a replacement of Professor Kurt Forster in HTC chaired by Professor Stanford Anderson has come to the conclusion that there are no senior candidates who are both acceptable and movable on a permanent basis. It has been decided to redirect the search to that of a tenure track position of assistant or associate professor with a visiting senior professor for one term each year. However, the award of permanent tenure this year to Professor David Friedman stabilizes the faculty in this teaching group.

PhD candidates and graduates in the HTC have received a number of awards and honors. Hilary Ballon was named to a two-year term in the Society of Fellows of Columbia University and appointed Assistant Professor in their highly respected Department of Art and Archaeology. Mark Jarzombek will be a Chester Dale Fellow at the Center for Advanced Studies in the Visual Arts, National Gallery, Washington, DC. August Sarnitz is Director of the Otto Wagner Archives, Vienna; and Peter Testa received a Gulbenkian Foundation grant for further research on and work with the architect, Alvaro Siza.

The history group’s PhD Forum was continued this year, offering seminars by seven distinguished scholars from the region. The HTC lecture series brought speakers from Japan, Paris, and Finland.

Last year eleven applicants were admitted to the MAS program as PhD candidates on an adhoc basis pending the development of a formal program for the MAS PhD. During the year a committee chaired by Professor Papert has developed a formal proposal for the MAS PhD program which has been submitted for comment to the Departmental PhD committee, Professor Anderson, and to the Dean of the Graduate School, Frank Perkins.
Visiting faculty in architectural design this fall were Professor Louis Sauer from Carnegie Mellon University who taught a Level III studio and Joan Sprague, Director of the Women's Institute in Boston, who taught an all women studio in Level II. In the spring, Elin Corneil directed a Level II-III studio assisted by Carmen Corneil, Professor from the University of Toronto. Two graduates of the Department, Daphne Petri ('76) and Julie Messervy ('78) were appointed as Instructors to teach design studios.

Professor Jan Wampler received the Boston Society of Architects Award for Design Excellence in Housing for his design of the Angela Westover House, congregate housing for the elderly in Jamaica Plain, MA.

Professor David Friedman was granted permanent tenure in the Department as a member of the HTC section. Visiting faculty in that group were John Jespersen from Brown University in the fall term and Professor Francoise Choay of the Universite de Paris VIII.

Director of the Media Laboratory, Professor Nicholas Negroponte, was named first Jerome B. Wiesner Professor of Media Technology. The chair was established in 1980 by a gift from the Schlumberger Technology Corporation in honor of Professor Wiesner. Professor Andrew Lippman was appointed to the NEC Career Development Professorship of Computers and Communications. A number of new faculty members joined the Laboratory this year. Dr. Arun Netravali who is the Director of the Computer Technology Research Laboratory at Bell Laboratories, accepted an appointment as Adjunct Professor. He will work primarily with the Advanced Television Research Program through the Media Laboratory. Dr. Alan Kay was appointed Lecturer. Professor David Zeltzer joined the faculty as Assistant Professor of Computer Graphics, and Dr. William Higginson was Visiting Professor of Media Technology working with the Learning Research Group.

Professor Robert O. Preusser retired at the end of this year after 31 years teaching at MIT. Professor Preusser has taught visual studies subjects in the Department since 1954 and in recent years has served as Director of Education for the Center for Advanced Visual Studies.

Professor Waclaw Zalewski took sabbatical leave in the spring term and Professor Anne Wagner took leave to do research for a book supported by a grant from the Provost's office.
This was a year of our faculty accomplishing new initiatives, among them new programs in planning for developing areas and in real estate development. At the same time we continued our efforts to discover and teach the central skills essential to effective practice of planning. It was a taxing agenda.

During the year we were visited by a site team on behalf of the newly adopted planning accreditation process, a joint effort of the American Institute of Certified Planners and the Association of Collegiate Schools of Planning. They have recommended our accreditation, without reservations, and in a generally lauditory report have offered a number of suggestions about how we might further strengthen our professional degree programs. We will address these in the coming year.

EDUCATIONAL PROGRAMS

The number of Course XI majors remained very small, although several of our undergraduate subjects experienced large enrollments encouraging us to add to our offerings. During the year the faculty debated alternative futures for our undergraduate program and concluded that the best course was to preserve the opportunity to major in our department with a custom-tailored program. However, we will concentrate on the larger need for general education about urban society by teaching applied subjects and offering an area of applications for the special analytical skills that MIT undergraduates acquire. We hope that the ongoing development of our school's computer resource laboratory will provide an avenue to attract new undergraduates our way. Professor Gary Marx coordinated our undergraduate program.

The year marked the beginning of our new developing areas option in our Master in City Planning program (MCP/DA) with eleven students enrolled. Professors Lloyd Rodwin and Ralph Gakenheimer jointly offered the new Comparative Planning Processes core subject and many other faculty participated in individual sessions. The addition of a new group of masters students also helped give new emphasis to third world development issues in the department and spawned a new student-faculty study group on Latin American Urban Studies (LAUS). The Special Interest Group in Urban Settlements (SIGUS), which includes faculty and students from both architecture and planning, again had an active year of seminars and workshops. Included were short courses by Alain C. Bertaud of the World Bank, Roberto Chavez of Nicaragua, Forbes W. Davidson of the Netherlands, and Marina W. Fernando of U.S. Save the Children.

The increased scope of our work in planning for developing areas led to the formation of a task force chaired by Professor Gakenheimer aimed at becoming clearer about the substantive directions we ought to emphasize. The task force, which included all the permanent faculty in this area in the department, singled out five areas as important to our future: the management of development efforts; the relationship of global economic trends to industrialization and more local development decisions; local land use and environmental planning; rural development; and the process of social development. We hope to make any future appointments in light of this agenda.

Our regular Master in City Planning (MCP) program continued in a form that was substantially similar to the previous year. Thirty five first-year students were enrolled and 41 completed theses in time for June graduation. Overall 94 students were enrolled in our masters programs. Professor Philip Clay headed our MCP committee and coordinated the core program.

Ten students began their PhD studies this past year, working closely with faculty mentors. During the year the PhD committee, headed by Professor Lawrence sussskind, made good progress in defining the routine fields for general examinations, and the committee instituted a new process for reviewing publicly dissertation proposals in lieu of being examined on the specific area of knowledge involved. We hope that these changes will simplify the review process and provide more guidance to students about the knowledge we expect them to master. Eight PhD students graduated during 1984-5.

The research forum organized by the PhD program focused during the fall on research by our faculty and staff. David Birch, Professors Bernard Frieden and Lynne Sagalyn, Professor Bennett Harrison and Professor Martin Rein made presentations. During the spring semester, the forum was organized by Professor Robert Fogelson and centered on historical studies. Professor Joel Tarr of Carnegie-Mellon University, Professor Sarah Deutsch of the MIT History faculty, Professor Clifton Yearley of SUNY-Buffalo and Professor Gwendolyn Wright of Columbia University made presentations.
While reported on elsewhere, five of our faculty under the capable direction of Professor Larry Bacow were involved in offering core subjects for the new M.S. in Real Estate Development program. A number of planning students enrolled in each of the subjects, and there was a healthy dialogue between those who wish to carry out development projects for private gain and those who wish to safeguard and pursue public objectives. We are even more persuaded of the value of having a real estate program along side our programs in city planning.

During the year the Computer Resource Laboratory moved to enlarged quarters and obtained considerably more equipment and software, largely through Project Athena. The Laboratory, ably directed by Professor Joseph Ferreira has helped raise the computer literacy rate of our students to about 80%, we estimate, a dramatic change from just two years ago.

After a ten year decline, applications to our MCP program rose this year to 159, partly on the strength of our new developing areas option. A total of 61 applicants were offered admission to the MCP program and 25 to the MCP/DA option, hoping to enroll 50 students in the two programs in September. Additionally, eight architecture students were accepted as candidates for dual degrees in our MCP programs. About 44 percent of those offered admission are from abroad and seven percent are minority students. Application numbers to our PhD program also rose slightly to 66. Fifteen applicants were offered admission and we hope that at least 12 will enroll. Eight of the incoming class are from abroad.

SPECIAL EDUCATION PROGRAMS

The Special Program for Urban and Regional Studies in developing areas (SPURS) completed its eighteenth year, under Professor Rodwin's direction. This year's 14 Fellows came from Bolivia, Brazil, Japan, Nepal, Netherlands, Nigeria, Philippines, Portugal, Tunisia, Turkey, Venezuela, United States, and Yugoslavia. In addition, Naomi Carmon from The Technion in Israel and Ludewit Vogh from the Technical University of Prague were in residence as SPURS associates. Members of the growing community of students and practitioners of planning in developing areas found the weekly SPURS seminar a good occasion for exchange of views. Speakers this year included: Professors Donald Lessard, Robert Rotberg, Donald Schuh, Judith Tendler, Gary Hack, Charles Sabel, Sherry Turkle, Beatriz Nofal, Hayward Alker and Jean Jackson; Naomi Carmon, Technion; Lester Gordon, Harvard; Asoka Bandarage, Brandeis; John Friedman, UCLA; William Dobele, Harvard; Charles Boyce, HABITAT; Tom Miller, Ford Foundation; Jianxu Deng, Shenzen University; Banarsi Kambo, Rajasthan; Edward Echeverria, World Bank; Alfred P. Van Huycck, PADC; Nathan Glazer, Harvard; Koichi Mera, World Bank; Merilee Grindle, Harvard; and Ben Higgins, Canada.

During June two one-week SPURS short courses were held for practitioners around the world. Their topics were complementary -- "The National Housing Experience" and "The Local Housing Experience" -- and many attended both sessions. Professor Rodwin and Arthur Row organized this year's summer courses.

The Community Fellows Program (CFP), under the direction of Professors Mel King and Yohel Camayd-Freixas, had six Fellows in residence. The work of Fellows centered on issues of youth employment, media and social relationships between Arab Americans and Black Americans. During the Fall, a special conference on the experience of Black mayors was sponsored by the department and organized by the CFP. Speakers included Mayors Harvey Gantt of Charlotte and Gus Newport of Berkeley, California, Professors King and Michael Piore, and a number of senior black and hispanic municipal officials.

Professor Susskind and members of the Program on Negotiation offered a special short course on Bargaining and Negotiation under the auspices of the Industrial Liaison Program, and a more expanded version as a special summer program.

Professor Ferreira and other faculty from the department offered a special short course on Microcomputers in Planning for practicing planners in the area.

As this report is written, this author is conducting a special six-week urban design studio in Beijing, China at Tsinghua University for graduate students at American universities and their Chinese counterparts.

RESEARCH

Most of the faculty were engaged in research during the year, and sponsored research projects are reported elsewhere by the Laboratory of Architecture and Planning. Thus, only brief mention will be made of projects.

Professor Karen Polenske studied the role of infrastructure in promoting regional economic growth, with a grant from the United States Department of Commerce.

Professor Susskind continued his direction of the Program on Negotiation, a joint effort with the Harvard Law School, and undertook further work on negotiated investment strategies in communities, negotiated rate-setting, and the resolution of environmental conflicts.
Professor Schin again coordinated the design research group which met regularly to discuss research and ideas during the year. Participants included Professors Aaron Fleisher, Hack and Ferreira, a number of colleagues from Architecture, and graduate students working on research in the area. Studies culminated in a two-day roundtable seminar at the end of May.

Professor Clay began new research on public-private initiatives to produce housing for the poor, with sponsorship from the Center for Real Estate Development.

Professor Mark Schuster conducted a comparative study of public and private financing of arts activities in Canada, the United States, and six European countries, made possible through a grant from the National Endowment for the Arts.

Professors Frieden and Sagalyn continued their research on public-private initiatives in downtown redevelopment.

Professor Camayd-Freixas conducted research on the demographics of the Hispanic community in Massachusetts, and on the social service needs of public housing tenants.

A number of faculty worked on developing computer capacity for teaching under the general umbrella of our schools Project Athena initiatives, coordinated by Professor Ferreira.

Professor Fogelson continued his research on the social history of armories and, during the year, saw the publication of his book *Pensions: The Hidden Cost of Public Safety*.

Professor Harrison continued research on the changing industrial structure of the United States economy and its impacts on employment and the distribution of income.

Professor Merrie Klapp completed work on her study of the political economy of oil in eleven countries.

Professor Marx initiated an important study of new technological forms of surveillance and their societal consequences.

Professor Rein worked on the upcoming family outlook report, to be published by the Joint Center for Housing Studies, and on a study of economic well-being in later years, sponsored by the National Institute on Aging.

Professor Rodwin served as study director for the United Nations - International Year of Shelter and Housing project to examine the linkages between shelter, settlement and development. He chaired a conference in April on the subject, whose participants also included Professor Gakenheimer, Strout, Sanyal, Peattie, Schön and Tendler.

Alan Strout conducted a study on aspects of North-South trade for UNIDO.

Professor Lance Taylor, with a grant from the Ford Foundation undertook a study of poor countries in the international system.

Professor William Wheaton did studies of aggregation in urban transportation systems, expectation on cycles in non-residential construction, and the spatial externalities of aggregate land rent.

David Birch did a variety of studies on the job formation process and initiated an important new study to forecast the office space needs in United States cities.

FACULTY

A number of our faculty were honored for their contributions during the past year.

Professor Frieden will be awarded the Class of 1942 Chair in recognition of his stature as one of the most influential members of the academic community in the planning field.

Professor Sagalyn was awarded the Class of 1922 Career Development Chair, recognizing her promise.

Professor Schön was chosen to receive the Billard Award and the Graduate Student Council Award for distinguished teaching in the department.

Professors Bacow and Wheeler were awarded first prize for legal scholarship by the Center for Public Resources in recognition of their book *Environmental Dispute Resolution* as the outstanding publication in the field of alternative dispute resolution in 1984.
After spending the year in the department as a visiting faculty member, Judith Tendler was appointed Professor of Political Economy with permanent tenure. She brings strength and distinction to the department in the study of development institutions.

Professor Beatriz Nofal from Argentina spent the spring semester as a visiting faculty member, teaching about theories of development and third-world industrialization.

Professors Polenske and Gakenheimer were visiting professors during the year at Montpellier University and the University of Lyon II, respectively, under a French program to bring distinguished faculty to that country.

Professors Tunney Lee and Langley Keyes continued their professional leaves, managing and giving policy direction to agencies of the Commonwealth.

Professors Debbie Stone of Political Science and Lance Taylor of Economics became joint appointments in the department.

At the end of the academic year James McKellar of the University of Calgary was appointed Visiting Professor of Real Estate Development and will serve as coordinator of the real estate educational program for the next two years.

LOOKING AHEAD

In continuing its effort to diversify its base, the department held a series of discussions with the Sloan School of Management and the Operations Research Center on creating new educational opportunities in the management of public services. We enter the new academic year hoping that these will mature into programs.

Job prospects appear bright for our graduates, and calls for better planning of urban areas both in the United States and abroad are frequently aired. We are optimistic about the role we can play in meeting these challenges. Yet there is much unfinished business: further contributions needed in the education of undergraduates, the need for new scholarship support that ultimately will determine who has access to our opportunities, and the continued desirability of expanding our research activities.

As we begin the year in which we will commemorate fifty years of graduating professional planners, we can take pride in the fact that we are the largest, oldest and arguably the finest program of its kind.

GARY HACK
The Aga Khan Program for Islamic Architecture (AKP), established in 1979, is jointly based at MIT and Harvard University to improve education, encourage research, and develop information resources for historians, architects, and urbanists planning for and building in the Muslim societies around the world. Generous gifts from His Highness the Aga Khan support the AKP through an endowment that provides for appointment of faculty, supports student financial aid, ensures library acquisitions and services in perpetuity, and funds seminars, research projects, and publications.

The 1984-1985 academic year has been a year of transition from the initial five years of program establishment to the next decade of development and expansion. It was a year highlighted by a visit in March 1985 by His Highness the Aga Khan who announced a 10 year renewal of the grant consisting of approximately $900,000 annually ensuring not only continuation but also expansion of AKP activities until 1995.

Faculty

The AKP has been codirected by Professor William L. Porter, Professor of Architecture and Planning, since its inception in 1979. Other MIT faculty include Professor Yasser Tabbaa, Aga Khan Assistant Professor of Architectural History, who provides historical coverage and a new appointment made to fill the MIT tenured chair in the field of Islamic architecture. In September 1984, the Department of Architecture appointed Professor Ronald B. Lewcock, formerly of Clare Hall, University of Cambridge, and an authority on restoration and conservation of buildings as well as Islamic history and architecture, as Aga Khan Professor of Architecture and Design for Islamic Cultures at MIT.

Academic Programs

As in past years, several graduate courses in Islamic architecture were offered by AKP faculty. In addition, planning and implementation of a new Design for Islamic Cultures track in the S.M.Arch.S. Degree Program were successful and the first students will be enrolled in the 1985-1986 academic year.

Student Support

The endowment funds provide support of doctoral students at both MIT and Harvard University and also allows for student travel grants each summer. At present, six MIT doctoral students are funded in whole or in part. Eight students received grants in summer 1984 for travel to China, India, Indonesia, Turkey, and Yemen. Eight grants were again given for student travel to China, Cyprus, Egypt, India, Malaysia, Syria, Tunisia, and Turkey this summer.

Library and Information Resources

In addition to an endowment that ensures library acquisitions and services, the Aga Khan has designated funds for worldwide collection and dissemination of information useful to scholars and practitioners. The Images System, a joint project of the AKP Documentation Center, Rotch Library Visual Collections, and the Harvard Fine Arts Library, is an experimental information storage component of these activities. This visual archive system uses a combination of optical videodisc and personal and mainframe computers to index 30,000 images. The academic year 1984-1985 marks the close of the initial phase and will lead to testing and evaluation of a prototype videodisc system.

Seminars, Lectures, Research Projects

Highlights of the 1984-1985 year include AKP participation in a calligraphy exhibition at Harvard University in March and April 1985 (Professor Tabbaa, MIT cosponsor) and a lecture by Mr. Hugo Houben (architect, Brussels) on earth construction in the spring of this year.

A major annual enterprise is the AKP seminar series, Designing in Islamic Cultures. The fifth seminar, "Design, Technology, and Logistics for Large Housing Projects" was held July 23-27, 1984 in Cambridge.
Speakers from MIT and Harvard University, China, Europe, India, the Middle East, Pakistan, and Singapore presented case studies from Muslim societies. It was once again an opportunity for over 100 participants from around the world to discuss and exchange experiences and information.

Planning and preparation for the next seminar, "Design for High Intensity Development" in Kuala Lumpur, Malaysia, began this spring as the centerpiece of a graduate studio course. This collaborative venture of the AKP at MIT, the University of Technology of Malaysia, and the Mara Institute of Technology will culminate in an international conference in Malaysia in August 1985.

WILLIAM PORTER
The Center for Advanced Visual Studies (CAVS) has continued its integrated work exploring collaborations between artists, scientists, and engineers and developing new media for expressive, predominantly artistic purposes.

CAVS director, Professor Otto Piene, and composer/laser artist, Paul Earls collaborated with the chancellor's office and scientists and artists of the Technische Universitaet Berlin in a series of environmental laser and sky events along the Strasse des 17. Juni in Berlin, with long-distance laser projections on a new flying inflatable which is also an inflatable building, "Berlin Star" (October, 1984).

Several CAVS artists (Harriet Casdin-Silver, Paul Earls, Professor Piene) contributed solo exhibitions in business settings to First Night in Boston - for environmental, all-city celebration of New Year's Eve, 1984/85.

A CAVS group collaborated on "Monocle" for "Mehr Licht" an exhibition of light works of the 20th century at the Staedtische Kunsthalle, Hamburg. "Monocle" combines optical and acoustical mirroring effects with the use of lasers as image projectors and sound correspondents.

A group of artists, engineers, and scholars of CAVS and Yeshiva University, New York, is currently developing a concept for a 1986 exhibition, "Sight/Insight" which uses contemporary media of art and technology to interpret religious content in a museum context.

The CAVS-developed travelling exhibition, SKY ART, has been circulated by the New England Foundation for the Arts to universities and museums nationally. The exhibition is based upon contributions by Digital Equipment Corporation (DEC); it uses video disc technology in an interactive format to invite user response.

The Center has recently received a National Endowment for the Arts (NEA) grant for "Desert Sun - Desert Moon" to initiate the '86 SKY ART Conference. The project will be laid out in portions of Owens Valley in California by collaborating artists Lowry Burgess, Dale Eldred, Elizabeth Goldring, Alvin Lucier, Professor Piene, Tal Streeter, and Tom Van Sant. It will use interactive environmental techniques such as reflection, afterburn, telecommunication, satellite-sensing, and remote laser carving in an effort to create a large-scale, temporary work.

Besides explorations of specific artistic language new vehicles to carry or amplify messages are being explored, e.g. the shuttle and other National Aeronautics and Space Administration (NASA) formats: Joe Davis with scheduled Get Away Specials (GAS) payloads; Lowry Burgess with a scheduled first non-scientific payload. Other individual work by CAVS fellows:

Mel Alexenberg has continued his development work towards an Israel Center for Advanced Visual Studies

Harriet Casdin-Silver: interactive holography exhibition at the New York Museum of Holography (with Dov Eylath)

Joe Davis: further development of remote-controlled steel cutting through slow-scan; voice transmission through light instruments

Paul Earls: Laser concert for the Niagara Falls centennial

Rus Gant: Documentation for laser discs for museum and educational use in China and USA of the "First Emperor of China" (the clay army and other archeological artifacts), in collaboration with Simmons College

Elizabeth Goldring: "The Inner Eye - from the Inside Out" (with Vin Grabill) - visual and psychographic inquiry of vision loss with the help of synthesizer and medical imaging techniques

Vin Grabill: "Image Orchestra in Motion" (with Betty Pahn and Dancers) - video and dance at Sanders Theater, Harvard University and Merce Cunningham studio, New York City

Chris Janney received a grant from the Browne Fund to design and build "Winterbreath" a participatory steam/sound fountain for Boston City Hall Plaza; in collaboration with Joan Brigham.

Titus Leber received grants to implement the video disc portions of his (Herman Hesse) "Bead Game" - a telenetwork, participatory performance game.
Todd Siler obtained a Fulbright grant to explore Indian religious imagery in context with his mind-image research.


CAVS director, Professor Piene, participated in a Zero Group environmental reconstruction at the Staatliche Kunsthalle, Duesseldorf (1984) and in the Zero RAUM permanent installation at the Kunstmuseum Duesseldorf (1985). He had a one-man exhibition at Galerie Schoeller Duesseldorf, 1984, and was principal artist for the 1985 Utah Arts Festival in Salt Lake City.

With his retirement Professor Robert Preusser concluded his role as director of education at CAVS.

CAVS Fellow Mel Alexenberg, currently president of Ramat Hanegev College in Israel, has been appointed Chairman of the Department of Fine Arts at Pratt Institute, Brooklyn, New York.

In the CAVS-provided environmental art section of the SMVisS graduate program the following theses were submitted: Walter Dent: HUMAN INTERACTION IN A TECHNOLOGICAL SOCIETY; A PHOTOGRAPHIC ESSAY; Sarah Geitz: PROGRAMMING MULTIPLE COMPUTERS FOR LIVE USE IN PERFORMANCE IN A LARGE-SCALE ENVIRONMENTAL PERFORMANCE; Uri Levi: WATERWORKS: AN ARTISTS' INQUIRY INTO THE DEVELOPMENT OF SPACES THAT PROMOTE CREATIVE INTERACTION; Bill Seaman: AN EXAMINATION OF A SPECIFIC NETWORK OF POETICS FROM THE REALM OF LANGUAGE–IMAGE–SOUND RELATIONS.

CAVS undergraduate offerings served approximately 250 students Institute-wide in such subjects as "Art and the Environment"; "The Artists Speak on Light"; "Life Drawing" and "Basic Photography for Architects".

OTTO PIENE
Center for Real Estate Development

During its second year, the Center for Real Estate Development (CRED) expanded into new areas of research, education, programs, and development. The Center was founded in 1984 by 64 corporate and individual members from throughout the United States. The Center now has a roster of 89 members, including national and international developers, investors, bankers, accountants, public sector agencies, lawyers, and architects. The Center recently launched a $1 million fund drive for its new educational facilities and ongoing research programs.

RESEARCH
The Center sponsors a wide-ranging research program on issues relevant to the real estate development and investment fields. The Center distributes to its members periodic working papers, technical reports, and conference proceedings based upon current research projects:

America's Office Needs: 1985-1995
A major study of the changing office market in America, incorporating data on demographic trends, employment growth by sector, and other relevant factors to project the demand for office space over the next decade.

Quality Control in Building Design and Construction in Japan
A study of the implications of the Japanese building experience for design and construction in the United States.

Downtown Shopping Malls and the New Public-Private Sector
A study of major new downtown retail development.

Private and Nonprofit Initiatives for Low-Cost Housing Rehabilitation
An evaluation of methods to reduce the cost of housing production and rehabilitation.

Comprehensive Building Evaluation
The development of procedures for evaluating the performance of existing buildings.

EDUCATION
The Center offers professional development courses and coordinates for the School of Architecture and Planning a new degree program, Master of Science in Real Estate Development (MSRED). The first class of 35 students of the MSRED program entered MIT in the fall of 1984 and will graduate this fall upon completion of the 12-month program. The graduate program draws on the faculty of the School of Architecture and Planning, the Department of Civil Engineering, and the Sloan School of Management.

Professional development courses were offered in January and July, 1985. Course topics for the 1985 summer program included Land Acquisition for Real Estate Development; Introduction to Microcomputers; the Life Care Community: A Case Study of Development Issues; Planning the First Development; Negotiation Skills for Real Estate Professionals; Industrialized Housing; The Small Residential Development; and Marketing Real Estate Developments.

PROGRAMS
The Center sponsors programs that focus on the major issues and trends in real estate development and foster ongoing support for the Center's research projects.

Member's Meetings
Annual and semiannual meetings for members are held with leaders from business and government to debate the most relevant topics of the day. Past meetings have addressed: "The Impact of Proposed Tax Reform on Real Estate Investment," and "Smart Buildings and the Future of Real Estate Development."

Conferences
One and two-day sessions explore areas of critical interest to members and others. Topics of past conferences have included "Future Opportunities for Pension Fund Investment in Real Estate," co-sponsored by the International Council of Shopping Centers, and "The Zoning Game Revisited," co-sponsored by the Lincoln Land Institute.
Seminars
Fall Seminars focus on major issues presented by leading visionaries of the development industry. The 1984 Fall Seminar, held on October 15th, featured James W. Rouse speaking on "The Rouse Approach to Urban Renewal: Making the Profit System Work for Social Change," co-sponsored by Bank of New England.

Lectures
The Center brings nationally-known real estate professionals to Boston to share their experience and analysis of current real estate projects. Speakers for the 1985 Spring Lecture Series were Daniel Rose of Rose Associates, Thomas Steele of Perini Land and Development Company, and Ernest Buckman of Oliver Realty Inc.

Regional Meetings
The Center co-sponsors a regional meeting once a year to acquaint a new area of the country with its programs, and to foster new members for the Center. The 1984 Spring Regional meeting was held in Houston, Texas, and was co-sponsored by Gerald D. Hines Interests.

CHARLES H. SPAULDING
The year 1984-85 was one of transition for the Laboratory of Architecture and Planning (LAP). The LAP continues to provide research development and management support for all faculty in the School, the Center for Real Estate Development (CRED) and the Aga Khan Program (AKP). In addition, this year the LAP began major development activity for a program in the research area of the technology and management of buildings and for the School’s East Asian Architecture and Planning Program (EAAP).

MAJOR RESEARCH DEVELOPMENT EFFORTS

The need to improve the technology of building is of great concern to our society. There is considerable demand to broaden educational opportunities in this area for our students in architecture, planning, and civil and mechanical engineering. Development efforts in the LAP will be devoted to expanding our research and to providing a base of activity to aid the educational aspects of projects. This year the LAP significantly increased its research in this area and built the strong organizational links needed to underpin further development.

The LAP already had a strong link to the Department of Mechanical Engineering through the MIT Joint Program for Energy Efficient Buildings and Systems (JPEEBS), for which the LAP provides the Associate Director and the administrative base. Also through JPEEBS the LAP started working with the MIT Center for Construction Research and Education (CCRE). The LAP led the efforts of MIT to initiate what we hope will be a long-term research program with the Korean Institute of Construction Technology (KICT). The LAP, JPEEBS and CCRE concluded a cooperative agreement for funded research with the Korean group this year. The LAP also joined CCRE in a number of research development efforts and began several collaborative research projects.

As part of the development efforts in the area of building technology, the LAP has also assumed the responsibility for shaping a building technology research program for the MIT-Harvard Joint Center for Housing Studies (JCHS). This effort has been made in collaboration with the JCHS Industry Policy Advisory Board. To further strengthen its capability in this area, the LAP established dialogues with several members of the Sloan School on the issue of internalization of the building industry. The LAP also assisted researchers from the new MIT Media Laboratory who wish to apply their laboratory's state-of-the-art technology to planning and design problems. The LAP has begun to work with the Aga Khan Program to shape a research agenda to be jointly implemented in the coming year. To further develop its sponsorship and research collaboration base, the LAP has initiated extensive contacts with building and construction interests in Japan and collaborative research is expected to evolve within the next year. LAP is also working with the CRED to develop a research track for the study of office and commercial buildings.

The LAP's work in both Japan and Korea has been made possible by the LAP-based MIT East Asian Architecture and Planning Program (EAAP), created in AY 83/84 and fully launched within the School and on the international scene this year. The EAAP was created in response to strong interest in this area by MIT faculty, students, and Boston area practitioners. The program focuses on the emerging nature of architectural and planning practice in times of transition in East Asia. EAAP is sponsoring research, promoting exchange of faculty and students, and encouraging curriculum development. After the first year, in which an advisory board was organized, the program in 1984-85 launched a broad range of activity and extensive connections with counterpart organizations in East Asia. The EAAP's second year of development met all the expectations of the participants. The major accomplishments of the year include: the EAAP's second annual conference, held in Osaka, Japan and cosponsored by Osaka University; advance plans for the third annual conference, to be held in Seoul, Korea, and cosponsored by Seoul National University; the aforementioned MIT-KICT cooperative research agreement; workshops with industry and government in Japan on various topics as "intelligent" buildings and maintenance of the building stock; an MIT-Tsinghua University summer urban design studio for US and Chinese students, held in Beijing, China; and planning for collaborative research projects with Tokyo University and Tokyo Institute of Technology. Through the LAP, the School of Architecture and Planning faculty made the keynote addresses at the first annual meeting of the Japan Association of Real Estate Sciences and laid the groundwork for collaborative research with CRED and Japanese groups. The EAAP this year also sponsored an MIT-based lecture series, attended by hundreds of MIT students and area practitioners and did the background work to EAAP's first sponsored course within SAP's curriculum, scheduled for Fall of 1985.

RESEARCH

Growing Segments of the US Economy includes a number of projects for indentifying rapidly growing segments in the US economy and of their job creation potential in a number of geographic areas of the US. Senior Research Scientist David Birch is the principal investigator for general projects funded by local governments and private industry. One such ongoing project is Developing a Small Business Monitoring System.
designed to continuously improve a longitudinal version of the Duns Market Identifier (DMI) to analyze the US economy. The goal is to produce a full, easily incremented DMI file that could yield a continuously rolling data set, to be routinely updated.

Building a Longitudinal Data Base for Canada is an effort to replicate kinds of analyses done in the US based on individual firm histories in Canada to enable the Canadian Government to identify the sources of employment growth within the Canadian economy in great detail. Dr. Birch is the principal investigator.

Research was concluded this year on Jobs for Connecticut's Future, a project which generated research about further job creation and educational needs. Connecticut was the prototype study in this project for which Dr. Birch was principal investigator. It was funded by the Ford Foundation and other corporate sources.

The US Real Estate Market project is identifying rapidly growing segments in the US economy and assessing their needs for commercial and industrial space. Dr. Birch is the principal investigator.

Physical Scale Models to Describe Energy Phenomena is a project for investigating thermal, ventilated and luminous environments. Principles of scale testing are being developed. Professor Harvey Bryan is the principal investigator. The work is funded by the Grunsfeld Foundation, MIT Cabot Solar Corporation and the Masonry Institute of America.

The staff of the Downtown Shopping Malls project will prepare case studies of the planning and building process for mixed mall development in downtown locations. Cooperative activities of public agencies and private developers will receive special attention. Professor Bernard Frieden is the principal investigator for this work funded by the Hahn Foundation.

Dr. Karen Polenske is principal investigator for Public Infrastructure and Regional Growth, a project funded by the US Economic Development Administration. The project focuses on the relationship between public investment and regional growth.

Housing Options for Sri Lanka is an analysis of housing options from that country, with particular emphasis on opportunities for government investment in infrastructure. Professors Nabeel Hamdi and Reinhard Goethert are co-principal investigators for the work funded by the National Housing Authority of Sri Lanka.

MIT Solar House V and the Crystal Pavilion addition, constructed on the MIT campus, continue to demonstrate direct-gain solar space heat through the use of new architectural finishing materials. Principal Research Associate Timothy E. Johnson is the principal investigator. Current work is funded by the US Department of Energy and private industry.

The Architectural Case Studies program continues to prepare prototype cases. Accessible design, energy conscious design, and managing the architectural design process are the topics of studies already completed. Staff members are now preparing a case book about case method teaching in architecture. LAP Director Michael L. Joroff is the principal investigator of the project, supported by the National Endowment for the Arts. A directory of available architectural case studies is being prepared in cooperation with the Bartlett School of Architecture and Planning, University College, London.

This year saw the completion of the first phase of a major research effort in Comprehensive Office Building Evaluation, a project funded by IBM Corporation and aimed at improving the coordination between management objectives and the design process. The project was carried out by Michael Joroff, Professor Ranko Bon, and LAP Research Affiliate John Zeisel, with Joroff serving as principal investigator.

Michael Joroff is also principal investigator for Research and Development of the Japanese Design and Construction Industry, an analysis of the institutional and organizational factors which impact the Japanese research and development process. Case studies of research about industrialized housing and interior environmental quality will be prepared.

The Consistent System project continues to develop a large collection of application software for data management and data analysis. Principal Research Scientist John Klensin is the principal investigator, and the work is supported by private industry.

Professors Patrick Purcell of the Department of Architecture and Robert Logcher of the Department of Civil Engineering serve as co-principal investigators for a project on Knowledge Based System Development for Facilities Planning. The primary objective of the project is to develop and evaluate IBM's expert system building tool known as PRISM as a knowledge based system for facilities planning. The project is funded by IBM Corporation.

The LAP serves as the overall administrative home for the Aga Khan Program in Islamic Architecture, which includes professorships and fellowships located in the Department of Architecture and a documentation project centered in Rotch Library. Summer institutes abroad, a faculty exchange program, publications, student travel grants, and other activities strengthen the program and link it with its counterpart
program at Harvard, with other programs at MIT, and with other institutions and individuals throughout the world. Professor William L. Porter is the Program's director.

This year saw the conclusion of the Design as Inquiry project, which explored and tested the ways in which the process of design can act as a rigorous form of inquiry. A team of planners, architects, and engineers investigated the distinctions between research of use to design and the use of design as a method of inquiry. Professor Donald Schön was the principal investigator for the work, funded by the National Endowment for the Arts.

MIT and the World Bank staff are working together developing an Interdisciplinary Approach to Project Design using the case study method. Professor Schön is serving as principal investigator for this research.

**DISSEMINATION OF RESEARCH FINDINGS**

The LAP has continued to disseminate the findings of its research projects to an expanding professional and public audience in the United States and abroad.

The LAP Publications Program has expanded its offerings to over 40 titles. These include publications produced by the MIT Joint Program for Energy Efficient Buildings and Systems, the Aga Khan Program and the Program for Public Negotiation. The Environmental Impact Assessment Review, edited by Research Associate Teresa Hill under the direction of Professor Lawrence Susskind, is now published by Elsevier Science Publishing Company, Inc. The Review's special issue published in 1984-85 was a 350-page volume on Assessing the Environmental Impacts of Offshore Oil and Gas Exploration and Development in the US, Canada, Ireland and the North Sea oil fields of the United Kingdom and Norway. The environmental design journal Places, edited by Professor William Porter with associates from MIT and the University of California at Berkeley, is now published as a regular journal fo the MIT Press. The publication originated as a LAP-based project funded by the National Endowment for the Arts. Open House International, a journal of housing, was created as a joint venture of the SAR group in The Netherlands and the LAP; Professor Nabeel Hamdi is the LAP-based editor. The journal has also been acquired by MIT Press.

**STAFF**

This year Sharon Trohon was promoted to fiscal officer of the LAP. Two new research associates were appointed to the research staff. Mary Dolden will work on development and special projects and Waichiro Hayashi will contribute to the East Asian Architecture and Planning Program.

Continuing on the core LAP staff were: Kathleen Reid, administrative officer and Judith Rodenbeck, staff assistant; Senior Research Scientists Thomas Piper, David L. Birch, and John Klesen; Research Associates Teresa Hill, Akhtar Badshah, Mary Jane Luchetti, William Parsons and Margaret Sevcenko, administrative staff member for the sponsored research staff. James McKellar was a visiting scholar in the LAP. Research affiliates included Samir Abdulac, Felicia Clark, William Coaldrake, Susan Gill, Hasan Khan, Gordon King, Jennifer Leaning, William Ronco, Bernard Spring, Thomas Vonier and Robertson Ward.

In the Aga Khan Program, Dorothea Williams became the new fiscal officer. Patricia Jensen and Shwu Chen joined the support staff.

The MIT Center for Real Estate Development (CRED) completed its second year under the directorship of Charles H. Spaulding. DUSP Associate Professor Lawrence Bacow continued to serve as Associate Director for Research, and Gisela Hoelzl became Associate Director for Programs this year. Continuing staff members included Maryann Taylor, Associate Director for Gifts and Grants; Inez Steele, staff administrative assistant, and support staff members Maria Vieira, Marianne O'Donnell, Sandra Bevins and Maria Frayler. All members of the CRED staff hold appointments through the LAP.

**DEVELOPMENT PLANS AND ISSUES**

The major developmental goal for 1984-85 has been the creation of an effective building technology research program. The director and staff of the LAP have been highly successful in putting together the beginnings of a major program of research in collaboration with private industry. Building technology research realted to the needs of industry will continue to form a major part of the LAP's plans for 1985-86. Other programs in the LAP, such as the East Asian Architecture and Planning Program, will involve cooperation with industrial groups at the international level. As this year's programs have demonstrated, private industry and foundation support can be effective in offsetting cutbacks in federal funding of research in some areas. The LAP will continue to facilitate and promote faculty research initiatives within the agenda of the School. It will provide a research base for collaborative projects involving members of the School and other departments in the Institute. Practicing architects and planners, alumni, members of the Visiting Committee and representatives of client organizations are encouraged to provide advice and assistance to LAP programs.

MICHAEL L. JOROFF
Despite an eight month delay, the academic year 1984-1985 saw the fulfillment of a long awaited dream: the physical establishment of the Media Laboratory. Ten separate groups, previously scattered in six different locations, came together under one roof, in building E15, the new Arts and Media Technology Building - a 110,000 square foot, I. M. Pei designed facility at 20 Ames Street. The period between February and June saw the commissioning of new laboratory facilities, of which the Epistemology and Learning Group was the first to move and Spatial Imaging Group was the last. The academic year concludes with a fully operational laboratory, with all of its constituent parts, with the exception of an experimental media facility expected to come on-line in March of 1986.

The physical existence of the Laboratory accompanies a financial and intellectual robustness, as well as a public recognition of the cultural timeliness of this venture. New initiatives in home computing, learning research, holography, graphics and the human interface are reflected in grants and contracts which start the new year with a Laboratory research budget in excess of $3 million. The research volume is significantly augmented by hardware grants to the laboratory, concurrent with the building's completion. Most notably, Digital Equipment Corporation and Wang Laboratories, Inc. each provided over $2.5 million of computer hardware for research. The result is a laboratory with one of the highest densities of computer resources per person at MIT.

New Research

The Laboratory's largest research program is funded by IBM and titled Home Computing. By January of 1985, this program expanded significantly to include a special and distinct effort in epistemology and learning entitled: "The School of the Future."

The initial work on Home Computing is under the direction of Mr. Walter R. Bender and has as its main goal the development of new means of delivering information to the home computing environment, and providing a rich and personal interface to casual users. A personally edited, electronically delivered newspaper has been developed as a test bed, wherein the home computer takes on the editorial tasks associated with database delivery and analysis. The year has concluded with significant progress in augmenting the home computing environment with low cost color hardcopy and computer-readable television broadcast.

The School of the Future project is under the direction of Professor Seymour A. Papert. In collaboration with the Hennigan School in Boston, the program is exploring high density computing and computational omnipresence in kindergarten through 12th grade. An average of two computers per child in half of the school is part of the general thrust of removing the teaching of computer programming as anything but a mere sidestory, and bringing the computer presence into the mainstream of all subjects. Teachers and students alike are expected to view the music they do on computers as music, the English as English, the math as math, and so on. The common denominator is the computer, assuming a role as transparent as that of the pencil.

The Spatial Imaging Group has entered into a major research agreement with General Motors, Inc. in large-scale synthetic holography. During the year, in collaboration with the Polaroid Corporation, the group undertook the invention of a new type of computer graphic hologram and produced an example that is serving as a highlight of the USA pavilion at EXPO '85, Tsukuba Science City, Japan. It is the first multi-color computer graphic hologram and, at a meter on a side, is the largest synthetic hologram anywhere. Professor Stephen Benton, director of the group, presented papers on the most recent advances at the meetings of the International Committee for Optics, The Optical Society of America, and the Society of Photo-Optical Instrumentation Engineers (chairing sessions at the latter two).

The year included a first major contract for the Visible Language Workshop (VLW), under the direction of Professor Muriel R. Cooper, from the German printing and production company Dr.-Ing. Rudolf HELL GmbH. The purpose of the contract is to bring design assistance into the graphics arena and to explore the combination of advanced image processing, typographics, and audio output. As the year concluded, work at the VLW, with incremental funding from Polaroid and IBM, included initiatives in 3-D computer graphics, personalized electronic mail, and personal graphics.

Another new research initiative in progress is work in the Human Interface Group by Dr. Richard A. Bolt, under a grant from the National Science Foundation. The purpose of the program is to bring eyes and eye-tracking into the human/computer dialogue. The work includes the creation of two companion programs, one which emulates a human observer and one which responds to the emulation by highlighting in color areas of inferred interest. Future work will include the substitution of a real human for the emulation as soon as the Laboratory acquires an eye-tracker.
Finally, we report on two major proposals generated over this academic year for the Defense Advanced Research Projects Agency. A contract is being prepared for one proposal in three-dimensional display technologies for command and control, which is aimed at integrating advanced display technologies in information systems. The other proposal for vision augmentation to speech recognition, which is scheduled to incorporate computer lip-reading as an adjacent to connected speech recognition is in the final approval stage.

Continued Research

Continuing research programs include: Advanced Telephony, Advanced Television, Computer Animation, Computer Music, and Film/Video.

The Advanced Telephony research project continued into its third year under the direction of Mr. Christopher M. Schmandt. This project explores intelligent, computer-mediated, voice communication over networks of the future. Current work has focused on the implementation of a voice driven network node, including: directional addressing of devices by voice using microphone arrays, parsing algorithms for error prone speech input, the use of task context to aid speech understanding, and schedule maintenance and organization. The work has incorporated the earlier and popular "phoneslave" project which simulates the behavior of a live telephone receptionist.

Work continued on the Advanced Television Research Program (ATRP), under the leadership of Professor William F. Schreiber. This program, which is funded by a consortium of American television broadcasting companies and their principal suppliers, has as its main goal the development of the scientific and technological bases for the improvement of picture and sound quality in broadcast television. During this period, progress was made in motion-compensated interpolation and enhancement, adaptive sharpening of color images, motion rendition, and the establishment of a computer simulation facility for high definition (built around a VAX 11/785 included in the DEC grant mentioned above). This program includes the evaluation of audience acceptance conducted by Professor W. Russell Neuman. The overall ATRP effort is jointly operated out of the Research Laboratory for Electronics and the Media Laboratory.

While Computer Animation is a continuing effort in its third year, it gained a new leader, Professor David Zeltzer, who joined the MIT faculty in the fall of 1984, as Assistant Professor of Media Technology. Professor Zeltzer brings an extensive computer science background to the problems of modelling, rendering, and controlling complex three dimensional scenes and articulated figures. As part of this effort, the Laboratory has acquired a low cost flight simulator for real-time three-dimensional graphics. The work is currently funded by a grant from Nippon Hoso Kyokai (NHK), Japan's public broadcasting corporation.

The Computer Music Group, under the direction of Professor Barry Vercoe, has continued to be active in both research and music production, with support from the Systems Development Foundation and Compusonics. Research efforts have developed a Synthetic Performer, in which machine recognition of performance and conducting gestures enable the computer to function as a skilled collaborator in chamber music performance. As well as solving real-time multiprogramming issues, the research has also addressed symbolic representation of scores using Lisp and Prolog disciplines, so as to support even more powerful manipulation in the future. The work is currently being conducted in collaboration with Institut de Recherche et de Coordination Acoustique/Musique (IRCAM), Paris, France. Music production has seen the completion of five major works by visiting composers, with funds from the Massachusetts Council on the Arts and Humanities.

Under the direction of Professor Richard Leacock, the Film/Video Section has conducted research on computer controlled video editing and on polylinear movies. This includes a videodisc editing system and a personal computer control system which replaces frame numbers with pictures of frames, allowing the user to freely shuffle scenes. The group has also completed several productions, including a piece on how Gaudi might have used computer aided design.

We report the existence of five discretionary research programs, funded by Polaroid Corporation, Hitachi, Ltd., Toshiba Corporation, Sanyo Electric Co., Ltd., and Online Computer Library Center. Each has contributed to the general stability of the Laboratory in its formative year.

Personnel

A number of changes and appointments at the Media Laboratory have accompanied its growth. Of major note are two Chairs awarded to Professors of Media Technology: The Wiesner Chair was awarded to Professor Nicholas Negroponte, the Laboratory's Director, and the NEC Career Development Chair was awarded to Professor Andrew Lippman.
Academic appointments connected with the Laboratory included a Visiting Associate Professorship in Epistemology and Learning for Dr. William Higginson, a continuing Visiting Associate Professor of Computer Graphics appointment for Mr. Patrick Purcell, a Lectureship for Dr. Alan Kay, and an Adjunct Professor of Media Technology appointment for Dr. Arun Netravali of Bell Laboratories. Other new and continuing academic appointments included: William Kelley, Peter Randlette, Jason Kinchen, and Steve Kettel as Technical Instructors; Benjamin Bergery, Glorianna Davenport, and John Gianvito as Lecturers; and Lee Silverman and Brian Swift as Instructors.

Research appointments, including those moved from other departments include: Mr. Marvin Denicoff and Mr. Ronald MacNeil as Principal Research Scientists; Mr. Barry Arons, Mr. Mario Bourgoin, and Ms. Denise Hilaillon as Temporary Research Associates; and, Mr. Miller Puckette and Mr. Curtis Roads as Research Associates with the Electronic Music Studio. Mr. Walter Bender and Mr. Chris Schmandt were both promoted to Principal Research Scientists, reflecting their research accomplishments and current responsibilities.

The Laboratory also reports the creation of the post of Assistant Director of Administration and Finance, to which Mr. Robert P. Greene was appointed. Mr. Greene brings 20 years of experience at MIT to managing the Media Laboratory's operations, which included this year's complexities of relocating into the new facility.

NICHOLAS P. NEGROPONTE
School of Engineering

Working with department heads and laboratory and center directors, the Dean's Office has issued a final report of the School's long range plan. Implementation of the various elements of this plan are underway. Several of the initiatives involving new undergraduate laboratories facilities have completed the fund raising activities for their support and are in the process of implementation. The REMERGENCE Laboratory, a joint initiative of the Departments of Civil and Mechanical Engineering to provide a facility for research in the extraction and utilization of materials, has assembled a major portion of its facilities during the past academic year. An effort to develop joint subject's and a more coordinated program in our controls educational offerings has resulted in a new control subject which is under development and which will be offered during the next academic year.

The area of curriculum development, and the preparation of texts and other educational materials, has been identified as a high priority need for the School. This year a significant number of curriculum development efforts are in progress and have been supported with the Gordon Curriculum Development Grant and other School funds in all of the academic departments. The School continues to participate actively in Project Athena with seventy-one activities underway to use computers in educational subjects.

For the past several years, the School has examined its activities in the area of Technology and Policy, with particular emphasis on its Center for Policy Alternatives and the Technology and Policy Master's Degree Program. The School participated in an interdepartmental, inter-school study of Technology, Policy, and Society. This committee, appointed by Provost Low, reviewed the policy and technology programs throughout the Institute, and made recommendations to strengthen the Institute's commitment to research and education relating to technology and policy. In particular the committee recommended that the School of Engineering undertake a major revision of its activities in this area to benefit the overall programs at the Institute. The Dean of Engineering appointed a committee to make recommendations to implement a new program centered in the School but with outreaching efforts to other programs at the Institute. As a result, effective June 1985, the new Center for Technology, Policy and Industrial Development was established with Professor Daniel Roos as its director. The creation of the Center strengthens the Institute's commitment to this important field and combines the activities of the Technology and Policy Program and the Center for Policy Alternatives. The School and the Institute have made a substantial commitment for the start-up expenses of the Center and the Japan Steel Industry Chair for Technology and Policy has been awarded to Professor Roos to further support the program.

The School continues to search for appropriate approaches towards research and education related to the design, management, manufacturing, and delivery of technological systems. As technological systems become increasingly sophisticated, the relationship of the processes from conception to delivery of a product must evolve into a well understood process. Under the leadership of Professor Kent Bowen, the School in cooperation with the Sloan School of Management has been exploring with many of our faculty methods for understanding and teaching the disciplines and integrating elements of this process. A variety of proposals and concepts have emerged and were further developed this year.

Undergraduate enrollment decreased slightly (2.36 percent) from 2,418 in 1983-84 to 2,361 in 1984-85, although enrollments increased in the Departments of Aeronautics and Astronautics (Aero/Astro) (11 percent), Electrical Engineering and Computer Science (3 percent), and Materials Science and Engineering (DMSE) (13 percent). The increase in the size of the sophomore class was greatest in DMSE (42 percent), while Aero/Astro and the Department of Civil Engineering also experienced growth in their sophomore enrollments (8 percent and 7 percent, respectively). Graduate enrollment in the School increased by 3.3 percent from 2,191 in 1983-84 to 2,263 in 1984-85.

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. This year the policy was amended to include funding of postdoctoral positions for women or minority candidates with good potential to become faculty members. During 1984-85 faculty positions were offered to four women and one minority. Two of these offers were for "special" positions. Three of the five offers were accepted.

The Second Summer Program will enter its seventh year of operation in the summer of 1985 with thirty-three students and eight companies participating. Its founder and Director, Professor Wesley L. Harris, will leave MIT July 1 to assume the position of Dean of Engineering at the University of Connecticut. Professor Harris will be succeeded by Professor Leon Trilling as Director of the Second Summer Program. The Program which started in 1979 with ten students provides an intensive summer educational and work experience to outstanding MIT minority engineering students following their freshman year.
BIOTECHNOLOGY PROCESSING ENGINEERING CENTER

In response to a National Science Foundation initiative to form engineering centers in a variety of universities in the US, the School proposed and was awarded funding for a new program focused on cross-disciplinary research and education in the area of biotechnology. This program, directed by Professor Daniel Wang, will concentrate on cross-disciplinary activities needed to translate discoveries in the biological sciences into successful commercial operations through fundamental engineering research and development. The educational objectives of the program are to create a new breed of professionals who will obtain the necessary foundations in the disciplines related to the development of biotechnological processes and systems. At the graduate level, the Department of Chemical Engineering in the School of Engineering and the Department of Applied Biological Sciences in the School of Science will develop a new interdepartmental program in biotechnology to educate professionals in this field. The program involves some fifteen faculty from the Departments of Chemical Engineering, Chemistry, Biology, and Applied Biological Sciences.

ENGINEERING INTERNSHIP PROGRAM

For the summer of 1985, 58 sophomores were placed in the Engineering Internship Program (EIP), compared with 53 for the summer of 1984, and 41 for the summer of 1983. The total enrollment is now 127 students, with 30 companies actively participating in the Program. Beginning at the end of the sophomore year, the EIP provides work experiences at a participating company during two undergraduate summers and one graduate summer and academic term. The Program leads to the simultaneous award of the S.B. and S.M. degrees with the S.M. thesis done at the company during the graduate work experience.

Companies continue to be attracted by the objectives of the Internship Program. In the summer of 1985, the General Electric Engine Business Group in Lynn, Massachusetts will be participating in the Program. The Program continues to grow at a controlled pace where the distribution of companies and work experience is consistent with the student distribution among the disciplines in the School. The expected steady-state level is about 200 students and 45-50 companies.

MANAGEMENT OF TECHNOLOGY PROGRAM

This Program, directed by Professor Edward Roberts in the Sloan School of Management, leads to the S.M. in Management of Technology awarded jointly by the School of Engineering and the Sloan School of Management and is described in the Sloan School of Management section of this report. The Program is aimed at engineers and scientists with at least five years of work experience and is designed to prepare these professionals for more senior roles in industry and government where they will establish and manage technology-based endeavors. The enrollment in this 12 month intensive Program grew from six in 1982-1983 to twenty this year.

POLYMER SCIENCE AND TECHNOLOGY PROGRAM

As the result of a series of initiatives taken by the School, a cooperative effort has resulted in a program that complements the traditional departmental pathways to the doctoral degree for students interested in fields of polymer science and technology. This effort, participated in jointly by the Departments of Chemical Engineering, Materials Science and Engineering, Mechanical Engineering, and the Department of Chemistry in the School of Science, provides a focus for all of the polymer-related activities at MIT. It specifically addresses the need for doctoral-level graduates who have a strong command of the full range of concepts which make the broad, interdisciplinary field of polymers rich in intellectual challenges and technological opportunities. The Program is responsible for a core curriculum, taken by all students in the Program, which provides a common base in the field of polymers. The Program is directed by Professor Robert Cohen.

TECHNOLOGY AND POLICY PROGRAM

This Program, directed by Professor Richard de Neufville, continues to provide a professional master's degree program in engineering complemented by policy and economic studies and to prepare individuals who can equally address questions of technology and policy in both the private and public sectors. It is international in scope in both its educational content and in the composition of its student body. The alumni, now over 100, are well placed in many industrial, consulting, and government positions in the US and abroad.

The renewed commitment by the Institute and the School of Engineering to this important area is attracting important new resources to Technology and Policy at MIT. The Program has also benefited this year from the guidance of an External Advisory Committee of distinguished leaders, academic, and government officials.

The core curriculum of the Program was extensively revamped this year under the direction of Professors Judith Kildow and Louis Buccarelli, and with the support of the School. This effort will play a major
role in the educational program of the new Center for Technology, Policy and Industrial Development as the Technology and Policy Program will henceforth be an integral part of that new Center.

SCHOOL APPOINTMENTS AND RESIGNATIONS

Professor H. Kent Bowen, Ford Professor of Engineering, was named Director of the Manufacturing Systems Engineering and Management Program this year. He was replaced as Director of the Materials Processing Center by Professor Ronald M. Latanision, Shell Distinguished Professor of Materials Science.

Professor Daniel Roos resigned his position as Director of the Center for Transportation Studies to become the first director of the Center for Technology, Policy, and Industrial Development. Professor Roos will also become the Japan Steel Industry Professor on July 1, 1985. The new Center encompasses the former Center for Policy Alternatives whose Director, Professor Nicholas Ashford, will resume his regular faculty duties as Associate Professor of Technology and Policy in the School of Engineering.

Professor James R. Melcher, Julius A. Stratton Professor of Electrical Engineering and Physics, was named Director of the Laboratory for Electronics and Electromagnetic Systems. He replaced Professor Thomas H. Lee who is on leave of absence while serving as Director of the International Institute for Applied Systems Analysis.

Associate Professor David E. Hardt will become the Director of the Laboratory for Manufacturing and Productivity on July 1, 1985, replacing Professor Nam P. Suh who is on leave of absence while serving as Assistant Director for the National Science Foundation.

Professor Jack L. Kerrebrock, Richard Cockburn MacLaurin Professor of Aeronautics and Astronautics, will become the Associate Dean of Engineering September 1, 1985, replacing Herbert H. Richardson who left MIT to assume the position of Dean of Engineering and Vice Chancellor at Texas A&M University.

GERALD L. WILSON
Continuing the trend of recent years, the Department of Aeronautics and Astronautics grew this year in numbers of students both undergraduate and graduate, in faculty complement and in research volume. A sense of commitment to Aerospace Engineering, to emerging new ventures both in space and in aeronautics, lends vitality to the activities of the Department and unity to the community of faculty, students and staff. The expansive mood is traceable in part to national commitments to the Space Station, to expanding military aircraft programs and to the recent growth of airline traffic, which combine to produce excellent employment opportunities for graduates of Course 16, and relatively abundant support for research. There is also increased industrial interest in cooperative research.

The Department has been especially fortunate in attracting several excellent new young faculty again this year. Dr. Lena Valavanis, an expert in optimal control, began teaching in January. After receiving her Ph.D. at Yale, she conducted research for several years in MIT's Laboratory for Information and Decision Systems. Assistant Professor Andreas von Flotow is interested in dynamics of large space structures. Having received his Ph.D. in this area at Stanford, he has spent the past academic year in Europe, working with various segments of the European space community and will join us in September. Dr. Michael Giles accepted an appointment as Assistant Professor effective July 1. His field is computational fluid dynamics. Assistant Professor Steven R. Hall has made large contributions during his doctoral research, to the Department's initiative in fault-tolerant control; as of July 1, he has joined our Division of Instrumentation, Guidance and Control, which continues to have the largest graduate student contingent in the Department. Effective July 1, Dr. Daniel E. Hastings of Oak Ridge National Laboratory will join the Department as Assistant Professor. His area of interest is gas physics; he will be developing a program of research and teaching on the environment experienced by spacecraft.

These faculty additions are consistent with the Department's Long Range Plan, which projected adding an average of two Assistant Professors to the faculty each year for several years, to replace expected retirements and other losses of faculty. As of July 1, the faculty of the Department comprises 25 Professors, 5 Associate Professors and 11 Assistant Professors.

Development of a more extensive research and teaching program in Astronautics is central to the Departmental Long Range Plan, and is proceeding space. An undergraduate subject 16.06, Space Gas Dynamics, was offered by Professor Wachman as an alternate or supplement to 16.02 Aerodynamics, and has been heavily subscribed. Professor Crawley offered a new subject, 16.601 Dynamics and Control of Space Structures. Some highlights of our space research are the completion of ASTROVAC, a large vacuum tank designed for study of the behavior of structures in space, the receipt by the Man-Vehicle Laboratory of a NASA Public Service Group Achievement Award for its research on Spacelab 1, and completion of all hardware for the EASE experiment.

This experiment on Experimental Assembly of Structures by Extravehicular Activity is notable in several ways. When it flies in the Space Shuttle in November 1985, it will be the first major space experiment for which the flight hardware has been designed and built by students. Professor David Akin has become the largest single employer of UROP students in carrying on this endeavor, providing opportunities for dozens of undergraduates to learn of the practical aspects of space experimentation.

The Monarch Group, under the leadership of John Langford and Mark Drela, officially received the Kremer Speed Prize in December 1984, for being first to complete a closed 1500 meter course with a human powered aircraft, while satisfying all rules to the satisfaction of the Royal Aeronautical Society. Monarch is now on permanent display in the entrance lobby of the Museum of Science, and the Human Powered Aircraft Group has launched a new project: to carry out in spirit the mythical flight of Daedalus, by flying under human power from Crete to Greece, a distance of about 100 km. The initial research and development phase of the project is proceeding with sponsorship from MIT and the Smithsonian Air and Space Museum.

Computers in Aerospace Education, one of the Department's major initiatives, embraces a number of activities. Under the sponsorship of Athena, ten faculty led by Professors Murman and Widnall have made considerable progress in use of computers for teaching fluid mechanics, a discipline in which visualization and dissection of the flow field can be very helpful. Professor McCune, for example, has prepared software which enables students to interactively study vorticity convection and unsteady flows. Jointly with Athena, Professor Elias has acquired for the Department a large-screen, computer driven, projection system which allows faculty to use computer graphics interactively with large groups of students. We see this as important not only for fluid mechanics, but for space dynamics and many other areas where visualization is difficult but essential to understanding.

UNDERGRADUATE PROGRAM

Continued growth and vitality characterizes the Course 16 undergraduate program. The growth shown in Table 1 is evidence of the popularity of aerospace engineering with MIT undergraduates, and their enthusiasm is infectious. The large numbers of students do make it difficult to maintain the close faculty-student relationships which have been charac-
teristic of Course 16.

The impact has been most severe in our Undergraduate Projects Laboratory, in which each student conceives, designs and carries out an individual experiment, then reports on it both orally and in written form. This imposes a large load of supervision on the faculty, and corresponding major demands on our laboratory facilities. Both are mitigated to some extent by students teaming, which we find is also a good educational experience. Some students use the facilities of sponsored research programs as well, but there is still a shortage of space and instrumentation. This year a gift from the John Fluke company helped a great deal. Professor John Hansman was responsible for the Laboratory, with collaboration from Professor Bussolari.

To increase efficiency of utilization of both space and academic support staff, the Department carried out a major reorganization of its shop facilities, consolidating all student shops into the basement of Bldg. 33, and other machine shop capabilities into Bldg. 31. This effort freed a large experimental space in Bldg. 41 for use by the Space Systems Laboratory and withal has met its objectives. The work was carried out by Course 16 staff and students at modest cost. The contributions of Professor Akin's group on the Space Systems Laboratory and the Undergraduate Projects Laboratory Staff under Allan Shaw are especially appreciated.

The Unified Engineering Textbook project is proceeding, albeit somewhat more slowly than had been hoped, with major contributions thus far from Professors Mar, Widnall, Martinez-Sanchez and Wachman. Our current objective is to have a complete first draft manuscript for the first semester available by September.

Professor Leon Trilling has been active in the Institute-wide development of Humanities offerings which bridge the gap between the classical humanities and engineering. This year he taught STS 502, "The Profession of Engineering," to a class of 40. He participated in the study of the Humanities Arts and Social Sciences Requirement which culminated in a meeting of Humanities and Engineering administrators at Woodstock. He has been elected Chairman of the council for the Understanding of Technology in Human Affairs. We expect to be fully involved in the reorganization of the MIT undergraduate program which is to take place in the next year or two.

**GRADUATE PROGRAM**

This year graduate enrollment in Course 16 increased markedly, with almost twice as many new students admitted for the fall semester as for the previous year. Two factors contributed: a large number of highly qualified applicants, and an increase in research support which led faculty to offer more Research Assistantships. It appears that the increase in undergraduate enrollments in aerospace engineering which occurred some three years ago, is now being felt at the graduate level.

The present level of 215 graduate students is near the maximum which can be comfortably supervised by the faculty, so that steps have been taken to limit the growth beyond this level.

**FACULTY NOTES**

Professor Sheila Widnall was elected this year to membership in the National Academy of Engineering, and also as a Fellow of the American Institute of Aeronautics and Astronautics. The Department now counts six active faculty as members of the NAE.

Associate Professor Edward F. Crawley has been named a "Presidential Young Investigator", with an accompanying discretionary research award of about $300,000 over the next five years.

Professor T. H. H. Pian's article on "Derivation of Element Thickness Matrices by Assumed Stress Distribution" was cited in Citation Classics as referred to in over 85 publications.

Professor Marten Landahl has completed a textbook on "Turbulence and Random Phenomena in Fluid Mechanics" with Eric Mollo-Christensen, formerly of Course 16. It will appear this year.

Adjunct Professor Richard Battin has been elected a fellow of the American Astronautical Society.

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**Table 1**

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<tbody>
<tr>
<td>Sophomores</td>
<td>53</td>
<td>70</td>
<td>78</td>
<td>91</td>
<td>86</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>Juniors</td>
<td>37</td>
<td>47</td>
<td>70</td>
<td>73</td>
<td>86</td>
<td>81</td>
<td>90</td>
</tr>
<tr>
<td>Seniors</td>
<td>45</td>
<td>41</td>
<td>55</td>
<td>62</td>
<td>85</td>
<td>81</td>
<td>93</td>
</tr>
<tr>
<td>Totals</td>
<td>135</td>
<td>158</td>
<td>203</td>
<td>226</td>
<td>257</td>
<td>262</td>
<td>282</td>
</tr>
</tbody>
</table>
Professor Edward M. Greitzer has accepted Directorship of the MIT Gas Turbine Laboratory.

Professor Eugene E. Covert received the Graduate Students Council Teaching Award for Course 16 for 1984/85.

Professor Jack L. Kerrebrock received the Course 16 Undergraduate Teaching Award for 1984/85.

Assistant Professors Joseph Haritonidis and Robert Kenyon have been promoted to Associate Professor effective July 1, 1985.

The Department was fortunate to have as Visiting Professors this year Professor Mitsuro Kurosaka from the University of Tennessee Space Institute, and Professor Isaac Greber, from Case Western Reserve University.

We were also pleased that the following Visiting Scholars from the People's Republic of China could share our environment and contribute to the Department's research:

- Gu, Jialiu from Northwestern Polytechnique University
- Gao, Weibin from Beijing Institute of Aeronautics and Astronautics
- Liang, Junxiang from the Chinese Aeronautical Establishment
- Ding, Ziming from Beijing Institute of Aeronautics and Astronautics
- Zhang, Jin from Beijing Institute of Aeronautics and Astronautics

This year Professor Norman Ham was on sabbatical leave, in part at Ames Research Center of NASA. One result is a patent for "Helicopter Individual Blade Control System".

Associate Professors William T. Thompkins and William Widnall have left the faculty effective July 1, 1985, Professor Thompkins to be in charge of Computational Fluid Mechanics at Northrop Corporation. We appreciate the contributions they have made to the Department and will miss them.

Professor Wesley Harris has accepted a position as Dean of Engineering at the University of Connecticut effective July 1, 1985. His departure is a serious loss to the Department and the Institute, as his leadership in minority affairs has been exemplary. We wish him well in his new venture.

We were saddened by the death in a soaring accident on June 19, 1985 of David Shapiro, a student in Course 16 and friend of many.

On June 28, I announced to the Faculty and Staff of Course 16 that I have accepted Dean Wilson's appointment as Associate Dean of Engineering effective September 1, 1985. I offer my thanks to the students, faculty and staff of Course 16, who have made my tenure as Head of Course 16 both rewarding and pleasant.

JACK L. KERREBROCK
Department of Chemical Engineering

The job market and the enrollment of undergraduates have both stabilized. The 115 B.S. graduates in the summer of 1985 will be succeeded by classes of 50-60 students. About 60 percent of these graduates will go on to graduate school, including 27 percent that will go to medical and law schools. The graduate student population remains at the 210 level, including 127 who have passed the Doctoral Qualifying Examinations. An increasing number of doctoral graduates are taking teaching positions at leading universities in recent years.

The world of chemical engineering is in a period of rapid change. New opportunities have arisen from scientific advances in fields such as biotechnology, microelectronic materials and devices, and computers and systems engineering. Competence and mastery of computers have become necessities for future chemical engineers. The maturing of petroleum refining and basic petrochemical industries has caused an accelerated industrial switch to higher value added specialty chemicals. Concerns about the adverse effects of toxic chemicals, waste disposal, and plant disasters have led to increased attention. The curriculum of future chemical engineers must prepare them to be adaptable and flexible to cope with a world of rapid changes.

The Biotechnology Process Engineering Center (BPEC) was established by a grant from the National Science Foundation in May of 1985. Under the direction of Professor Daniel I. C. Wang, 15 faculty members from three departments in two schools of the Institute have made a major commitment to the Center's education and research programs. It is the intent of the BPEC to establish well-targeted efforts to advance the research and training of engineers to solve the problems associated with utilization of biotechnology. These goals will be attained through the training of a new breed of professionals through creative interdisciplinary education and research, the implementation of synergistic and imaginative programs through cross-disciplinary interactions, and continuous interactions with industry.

The Hoyt C. Hottel Lectureship was formally inaugurated on April 12 by Professor Emeritus Hoyt C. Hottel with his presentation entitled "The Fiery Furnace". Over 150 guests joined Professor Hottel after the lecture at a reception and dinner in his honor at the Faculty Club. The Hoyt C. Hottel Lectureship recognizes Professor Hottel's contributions to the intellectual climate of the Chemical Engineering Department, the encouragement of five generations of students, and the foundation and direction of the Fuels Research Laboratory. Future Hottel Lecturers will be welcomed to MIT for short periods of residency to organize seminars and mini-courses and present a formal lecture in honor of Professor Hottel.

UNDERGRADUATE PROGRAM

The following table shows the trends in undergraduate enrollment:

<table>
<thead>
<tr>
<th></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>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomores</td>
<td>107</td>
<td>99</td>
<td>127</td>
<td>133</td>
<td>59</td>
<td>61</td>
</tr>
<tr>
<td>Juniors</td>
<td>111</td>
<td>109</td>
<td>104</td>
<td>112</td>
<td>105</td>
<td>47</td>
</tr>
<tr>
<td>Seniors</td>
<td>117</td>
<td>111</td>
<td>111</td>
<td>111</td>
<td>116</td>
<td>115</td>
</tr>
<tr>
<td>TOTAL</td>
<td>335</td>
<td>319</td>
<td>342</td>
<td>356</td>
<td>280</td>
<td>223</td>
</tr>
</tbody>
</table>

Freshmen interest in our introductory chemical engineering courses and an improving job market indicate that sophomore registration for 1985-1986 will probably be the same or slightly greater than the last two years. The 1982-1983 registration of 133 greatly stressed our facilities and faculty. A level of 60-80 sophomore registration is believed to be approximately optimum.

To meet the challenge and need of integrating computers into Chemical Engineering education, course 10.01 Engineering Concepts and Computer Methods was offered for
the first time this spring. Developed by a team of Chemical Engineering faculty under the leadership of Professor Ulrich Suter and supported by the Project Athena Resource Allocation Committee/DEC, this course has been assigned required status by the department. In order to properly calibrate the courseware, access this first time was limited to freshmen. Enrollment was further restricted by hardware limitations, and a class of 35, admitted from 58 preregistered, took part in the inaugural semester. The main objectives of the course are to provide students with an overview of Chemical Engineering, a solid grasp of basic engineering concepts, and functional computer literacy on the Athena System. Course material was comprised of structure of the Chemical Products Industry; degrees of freedom, balances, and stoichiometry; rate phenomena and equilibria; and synthesis and flowsheeting. At the same time a "tool kit" of essential computer skills in the Athena environment was taught, primarily through an extensive set of homework problems.

Twenty-one students participated in the second year of 10.27 Undergraduate Chemical Engineering Process Laboratory. The experimental base was expanded this year to include a masters. While the number of students obtaining the Masters Degree in Chemical Engineering Practice is about constant, the number obtaining a research masters degree has decreased drastically. This trend is, at least in part, caused by the increasing difficulty of supporting graduate students at the masters level.

The Graduate Program in Polymer Science and Technology, An Interdepartmental Program in the Schools of Engineering and Science (PPST) was formally initiated in the spring. Under the directorship of Professor Robert E. Cohen, faculty from the MIT Departments of Chemistry, Mechanical Engineering, Materials Science and Engineering, and Chemical Engineering are developing a unified graduate-level polymer curriculum which will cover topics ranging from the molecular level to the continuum view of polymers. Seed funds obtained from the Dean of Engineering and the Dean of Science have made this development possible. The core curriculum, embellished with advanced-topic electives, will serve as the intellectual pathway for a small group of doctoral students who, from the outset of their graduate studies, wish to specialize in the interdisciplinary field of polymers rather than follow a traditional departmental route to the doctoral degree. The first entering class of about 10 students is targeted for Fall of 1986. At steady state operation, a total of 40 PPST students in residence is anticipated.

During the year a set of ten seminar courses was initiated. These courses focus on areas of graduate research interest such as fluid mechanics, gas-solid reactions, polymer science, catalysis, etc. An opportunity is offered for graduate students working in these areas to discuss their research, to undertake study in an area of mutual interest, and to interact with invited speakers. Typically, two to four faculty participated in each seminar.

The following table shows the trends in graduate enrollment:

<table>
<thead>
<tr>
<th>Years</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>
</tr>
</thead>
<tbody>
<tr>
<td>Masters</td>
<td>128</td>
<td>105</td>
<td>130</td>
<td>145</td>
<td>93</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>Doctoral</td>
<td>74</td>
<td>73</td>
<td>77</td>
<td>85</td>
<td>115</td>
<td>132</td>
<td>127</td>
</tr>
<tr>
<td>TOTAL</td>
<td>202</td>
<td>228</td>
<td>207</td>
<td>230</td>
<td>208</td>
<td>207</td>
<td>204</td>
</tr>
</tbody>
</table>

While the total number of graduate students is approximately constant, an increasing fraction of graduate students enter the Ph.D. program directly without obtaining a masters. While the number of students obtaining the Masters Degree in Chemical Engineering Practice is about constant, the number obtaining a research masters degree has decreased drastically. This trend is, at least in part, caused by the increasing difficulty of supporting graduate students at the masters level.
The Practice School matriculated 36 students last year, 35 percent enrolled with our doctoral program and the balance distributed between the five-year program for MIT undergraduates and the SM Practice School Program. Albany station projects were again under the direction of Assistant Professor Christopher Guzy while the Bethlehem Station operated under newly appointed Assistant Professor Robert Sproull. The Brookhaven Station completed its second summer of operation under the direction of Professor Jefferson Tester and Professor Alan Hatton at Brookhaven National Laboratory which is operated by Associated Universities, Inc., for the U.S. Department of Energy. Negotiations between MIT and NL/Treating Chemicals have culminated in a new summer station at the NL plant in Houston, Texas. Twelve students will participate in the program this summer under Assistant Professor Robert Hanlon's direction.

The Visiting Committee at its meeting in May acknowledged the progress that has been made in strengthening the Practice School program. They endorsed the efforts of the "Friends of the Practice School" recognizing that a strong industrial base of support is needed. In the Phase II program, each sponsoring Company will be asked to pledge $15,000 per year for a three-year period to provide fellowship aid for Practice School students. The overall goal is to raise $400,000 of support. In addition, over 2,000 Practice School alumni will be approached during the coming year to help support the fellowship program. Ralph Landau's generous endowment to the Practice School will enable us to support two students per year as recipients of the Ralph Landau Fellowship in Chemical Engineering Practice.

RESEARCH

Combined interdisciplinary and departmental research for which Department faculty were responsible totaled approximately $6.6 million in 1984-85, compared to $6.1 million in 1983-84 and $5.3 million in 1982-83. The research volume generated by the Department alone was approximately $3.3 million compared to $2.8 million in 1983-84 and $2.3 million in 1982-83.

Industrial support for research surpassed government support of the Department this past year.

As mentioned previously, this year has marked the beginning of a major NSF research grant in the area of biotechnology.

FACULTY AND STAFF

Two faculty members in the department have assumed Emeritus status, Professor Glenn C. Williams and Professor Robert C. Reid.

Professor Williams joined the department as an instructor in 1940 while completing his Sc.D. and achieved the rank of full professor in 1954. His distinguished career in fuels and combustion research is highlighted by his association with the Fuels Research Laboratory since 1942; directorship of the Torpedo Fuels Laboratory from 1944-46; active membership on many governmental advisory boards; and presidency of the Combustion Institute in the 1970's, which awarded him the Sir Alfred Egerton Medal in 1980. He was awarded the Certificate for Distinguished Service to Naval Ordnance Development in 1945 and in 1948 the Army-Navy Certificate of Appreciation in recognition of outstanding civilian service rendered during World War II. His service to the department in the capacity of Chairman of the Graduate Student Committee and Graduate Student Advisor is unparalleled. For over 40 years Professor Williams guided the activities and research of the multitude of graduate students who passed through the department.

Professor Reid was appointed Director of the Oak Ridge Engineering Practice School in 1954, full professor in 1965, and named the Chevron Professor of Chemical Engineering in 1981. His research and teaching in thermodynamics has culminated in over 100 publications and five books. The second edition of Thermodynamics and Its Applications (with M. Modell) was published by Prentice-Hall Book Co. in 1983. He has twice received the Outstanding Teacher Award from the Chemical Engineering Graduate Committee. In 1976 he was awarded the Warren K. Lewis Award by the American Institute of Chemical Engineers (AIChE) in recognition of extraordinary classroom teaching. His association with the AIChE includes responsibilities as past director, member of the Awards Committee, and Editor of the AIChE Journal. His tenure as editor (1970-76) saw the revitalization of the publication and its
return to a preeminent position in the field. Professor Reid was elected to membership in the National Academy of Engineering in 1980.

The formation of the Robert Reid and Glenn Williams Fellowship Fund was announced on May 11 by Professor James Wei. Samuel W. Bodman (Sc.D. 1964), President of Fidelity Management Research Co. of Boston, has provided the initial funding for the Fellowship in gratitude "...to both men who served as constant sources of support to hundreds of chemical engineering graduate students."

Gregory N. Stephanopoulos has been appointed full professor in the department, strengthening the areas of quantitative analysis and control of bioconversion processes.

Robert D. Sproull has been appointed Assistant Professor and Station Director in the School of Chemical Engineering Practice. He will direct operations at the Bethlehem Station.

Promotions during the past year include: William M. Deen to full professor; Ulrich W. Suter to associate professor with tenure; and Herbert H. Sawin to associate professor without tenure.

Dr. Maria Flytzani-Stephanopoulos and Dr. Ronald Tompkins were appointed Principal Research Associates in the Department.

Internationally distinguished visiting scientists and scholars to the Department included Pierre Adler (CNRS, France), Professor D. A. Lauffenburger (University of Pennsylvania), Dr. C.G. Wilson (IBM Corporation), and Dr. Thomas Peterson (University of Arizona).

HONORS AND AWARDS

Professor Janos M. Beer has been named the 1984/85 recipient of the Melchett Medal, the senior international award of the London based Institute of Energy, for his contributions to combustion science and technology.

Professor Robert A. Brown received the Graduate Student Council Award for teaching in the Department.

Professor Adel F. Sarofim received the Sir Alfred Egerton Gold Medal at the Twentieth International Symposium on Combustion in recognition of his "distinguished, continuing and encouraging contributions to the field of combustion." He is also the co-recipient of the Kuwait Prize for Science.

Professor Jack B. Howard was presented the Silver Combustion Medal by the Combustion Institute recognizing the excellence of a paper he and Dr. James D. Bittner presented at the previous symposium.

Professor John F. Brady and Professor T. Alan Hatton were designated Presidential Young Investigators by the National Science Foundation.

Professor Brady was the recipient of the James Lago Young Faculty Award granted by Merck and Co., Inc.

A special edition of Chemical Engineering Communications was published in honor of Professor Edward W. Merrill's receipt of the 1983 Alpha Chi Sigma AIChE Award and his 60th birthday.

A Russian edition of Heterogeneous Catalysis in Practice by Professor Charles N. Satterfield was published under the imprint of MIR, Moscow, U.S.S.R.


Professor Daniel I. C. Wang was elected to membership in the American Academy of Arts and Sciences.

Principal Research Associate Dr. Martin Yarmush was awarded a major scholarship in biomedical science by the Lucille P. Markey Charitable Trust.
The Department's Awards Day Ceremonies were held on May 8 with Professor James Wei presiding. The following awards were announced: Dow Outstanding Junior Award to Gina Buccellato; AICHE Annual Chapter Scholarship Award to Karen Lee (junior); American Institute of Chemists to Thomas Foo (senior); The Robert T. Haslam Cup to David Karohl (senior); The Rosemary J. Wojtowicz Memorial Prize in Chemical Engineering Practice to Robert King (graduate); The Roger de Friez Hunneman Prize to Maheswaran Surendra (senior); The Chemical Engineering Department Special Service Award to David Okamoto (senior) and Julia DiCorleto (graduate); Eastman Kodak Scholarship to Martha Beverage (sophomore); Chemical Engineering Outstanding Employee Award to Lisa Gould; and seniors David Karohl, Maheswaran Surendra, and Arline Yen were elected to Phi Beta Kappa. Viia Valge, a Practice School alumnus, was selected for inclusion in the 1985 edition of Who's Who Among Students in American Universities and Colleges.

Inducted into Tau Beta Pi this year were Scott A. Berceli, Gina M. Buccellato, Merit E. Cudkowicz, Thomas G. Eccles III, Josiah Friedlander, David A. Karohl, Karen K. Lee, David T. Okamoto, Snehal S. Patel, Erica S. Shane, Robert J. Struble, and Linda Yang.

JAMES WEI
INTRODUCTION

During this past year, the Department of Civil Engineering held an Alumni Colloquium to commemorate its 120th Anniversary. With attendance close to 300, this event was a substantial success, both in continuing the development of strong alumni ties and in articulating a future intellectual agenda for the Department, the profession and the construction industry. The theme of the colloquium was "The New Technology of Civil Engineering: Challenges for the Year 2000", and as this suggests, the focus of the talks were on the new directions civil engineering will take, under the impetus of the extraordinary advances in technology in areas such as computers and information science, materials, robotics and automation, instrumentation and nondestructive testing.

As stated in the program:

"The fundamental strategic issue facing the civil engineering profession and the construction industry is the integration and utilization of new technologies and methodologies in the solution of the critical problems of modern society. The organizations that will be able to compete and contribute nationally and internationally are those that understand and successfully utilize these new technologies and methodologies. The purpose of this plenary session is to describe these concepts and their application to improving productivity in engineering, construction, field monitoring and inspection, redeveloping our decaying infrastructure, protecting our supply of clean water from hazardous wastes, and our continuing search for energy resources".

In the morning, after introductory remarks by Professor Gerald L. Wilson, Dean of the School of Engineering, and Professor Joseph M. Sussman, Head of the Department of Civil Engineering, a series of plenary addresses were presented.

Professor Fred Moavenzadeh spoke on "Technology and Productivity in Engineered Systems: Applications in Materials"; Professor Robert D. Logcher discussed "The Computer and Civil Engineering: Future Directions and Implications"; Professor Gregory B. Baecher spoke on "Robotics and Automation: Technologies and Applications"; Professor David H. Marks discussed "The Infrastructure Problem: The Opportunity for the Development of a New Kind of Professional"; Professor Rafael L. Bras presented a talk on "Developing and Protecting our Water Resources: A Challenge for Science and Technology"; Professor Charles C. Ladd spoke on "Energy Extraction in Extreme Environments: The Challenge of Arctic Engineering". The luncheon address was given by Professor Steven R. Lerman on "Project Athena - A Major Experiment in Computers in Education at MIT".

In the afternoon, parallel sessions describing the programs of the Constructed Facilities Division (CFD), Transportation Systems Division (TSD), Water Resources and Environmental Engineering Division (WREE), and Center for Construction Research & Education (CC&RE) were presented. The closing banquet included remarks by Dr. Harl Aldrich, Chairman of the Department of Civil Engineering Visiting Committee, Mr. Charles L. Miller, Head of the Department of Civil Engineering from 1961-1970, and Professor Frank E. Perkins, Dean of the Graduate School and Associate Provost, and Head of the Department of Civil Engineering from 1975-1980.

We have outlined the content of the colloquium in such detail because its substance reflects the major recent initiatives taken by the Department as it anticipates the critical issues and challenges facing the profession and the construction industry. We are pleased that our alumni responded so well to this event, both in the sense of the number attending and in the substantive contributions they made prior to and during the colloquium in helping the Department to develop these concepts.

Undergraduate Program

The Department continues in its commitment to undergraduate education. We are working to attract undergraduates with a primary interest in Civil Engineering and in further developing service subjects of interest to undergraduates across the Institute.

We continue a variety of activities aimed at providing opportunities for undergraduates to participate in our program, including an active Undergraduate Research Opportunities Program, under the direction of Professor Harold Hemond; a Student Chapter of the American Society of Civil Engineers, under the direction of Professor John Slater; a rejuvenated Chi Epsilon Chapter which undertook several projects, advised by Dr. John Germaine; the offering of a number of undergraduate seminars in areas spanning the Department; several special programs such as the "Dueling Towers" Contest during Independent Activities
Period noted elsewhere in this report; and special subject offerings focusing on civil engineering issues of local interest, such as the Harvard Bridge, the Hingham/Boston Ferry, and the Central Artery Reconstruction.

During this past year, TSD initiated the planning for a new undergraduate curriculum focusing on operations analysis, information systems, and infrastructure planning and design. While this effort is in its preliminary stages, some important new subjects that will form the basis for this program have already been developed as follows:

1.101 Decision Analysis Laboratory - Professor Richard de Neufville
1.115 Statistical Applications in Civil Engineering - Professors Moshe Ben-Akiva and Nigel Wilson
1.21 Transportation Infrastructure - Mr. Michael Markow

All three subjects are designed to attract students from outside the transportation field and to some extent outside Civil Engineering, and all will be taught for the first time in academic year 1985/86 (although the Decision Analysis subject is being taught experimentally this spring as an undergraduate seminar).

The undergraduate laboratory subjects were a major focus of activity, with a substantial amount of curriculum development activity devoted to the following:

1.105 Structural Engineering Laboratory - Professor Lorna Gibson
1.106 Laboratory Projects in Environmental Fluid Mechanics - Dr. Eric Adams
1.107 Aquatic Chemistry and Biology Laboratory - Professor Philip Gschwend

The Department continued its focus on the development of subjects of general interest to MIT undergraduates. The redevelopment of subject 1.00 Introduction to Computers and Engineering Problem Solving, as one of the most popular computer offerings at the Institute, continued under the leadership of Professor George Kocur and Professor Eduardo Kausel. This past year, the Department took on the responsibility for 1.12 Computer Models of Physical and Engineering Systems, an engineering school-wide elective, and Professor S. Shyam Sunder put considerable effort into the development of this subject.

We note that undergraduate interest in majoring in Civil Engineering, while improved, is still at a level lower than the Department would like. This reflects national trends and starting salary levels for graduates. Many of the Civil Engineering faculty feel the need for a substantial reexamination of our undergraduate program, the last such effort having taken place in 1980. This process began in an exploratory way this past year and will continue at an accelerated pace next year.

Graduate Program

The graduate program of the Department continues to be attractive to a number of students, nationally and internationally. Applications were up about 10 percent this past year, and enrollment exceeds 200 students. The Department had an active year in the development of new subject material. New subjects include:

1.45 Construction Finance - Dr. James Paddock
1.545 Fracture and Fatigue Control in Engineering Structures - Professor Victor Li
1.711 Dynamic Hydrology and 1.713 Hydroclimatology - Professor Peter Eagleson
1.724 Groundwater Modeling - Professor Dennis McLaughlin

Substantial development was also performed by Professor Gibson on 1.592 Mechanical Behavior of Construction Materials, by Professor McLaughlin on 1.731 Optimization Methods of Water Resource Management and 1.732 Probabilistic Methods for Water Resource Management, by Professor Ole Madsen on 1.67 Sediment Transport and Coastal Processes, by Professor W. Kendall Melville on 1.64 Dynamics of Stratified Fluids, by Professor Amr Azzouz on 1.368 Computer Aided Analysis in Geotechnical Engineering, by Professor Harold Hemond on 1.75 Limnology and Wetland Ecology and on 1.723 Subsurface Water Quality, and by Professor Ben-Akiva, Mr. Thomas Humphrey, and Mr. Michael Markow on 1.242 Highway Engineering. Professor Francois Morel offered a new experimental subject in Particles in Natural Water. Professor Slater offered one in Computer-Aided Structural Design, and Professor Jerome Connor offered one in Knowledge-Based Systems.

Program Development

In this year's report, we highlight three major program development initiatives, each of which have broad implications for the future directions in our Department.

1. Program with the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers.

In a major Department-wide initiative spearheaded by Professor David Marks working through the Center for Construction Research & Education, the Department developed a research program with the U.S. Army
Construction Engineering Research Laboratory (CERL), in Champaign, Illinois. CERL's mission is to find the best ways to plan, design, build, operate, maintain and repair construction projects and facilities for the more than 150 army installations in the continental United States and overseas. CERL is an industry catalyst in advancing construction and related professions.

This past year CERL began funding at MIT in a broad range of construction related topics. Working closely with CERL investigators, MIT Civil Engineering faculty, students, and staff are presently involved in funded CERL research in maintenance performance modeling in civil works, expert systems for the maintenance of lock and dam structures, technology assessment of non-destructive testing strategies in civil works condition assessment, optimization of maintenance strategies, robotics for underground pipeline leak detection, artificial intelligence methods for constrained resource scheduling, composite materials evaluation and testing, improved project management reporting and evaluation strategies based on expert systems approaches and hazardous and toxic waste monitoring technology.

In addition, several new research areas involving materials, analysis methods for hazardous waste management, underground construction technology, facilities management, and facility planning are under discussion. Faculty involved in this program are Professors Marks, Logcher, Connor, Slater, Gibson, Hemond, Gregory Baecher, and Research Staff members Mr. Markow and Dr. Kenneth Maser.

2. REMERGENCE Laboratory

The REMERGENCE Laboratory (for experimentation in Resource Extraction, Materials and Energy, Reservoir, Geotechnical, Environmental and Construction Engineering) is a joint endeavor of the Departments of Civil Engineering, Mechanical Engineering, Ocean Engineering, Materials Science and Engineering, and the Department of Earth, Atmospheric and Planetary Sciences. The laboratory is based on the concept that to effectively address a number of problems of national and international importance (e.g., infrastructure renewal, development of energy and mineral resources, waste disposal and storage), we need research to characterize material and structural response, for both natural and artificial materials and structures.

Many common principles, methodologies and techniques, developed from both experimentation and theory, unite our understanding of materials and structures. At present, however, theory has proceeded far beyond what has been physically demonstrated. We need to perform experiments on these complex materials and structures to improve our overall level of understanding.

The REMERGENCE Laboratory is intended to enhance our physical understanding of materials and structures through the development of facilities for research and teaching and through the synergism brought about by individuals of diverse backgrounds working at the same facility. This exchange is a unifying objective of REMERGENCE; it results in increased intellectual stimulation and contributes to the expanding fund of knowledge in totally new and unexpected ways. As a shared facility, REMERGENCE allows the optimum use of the major equipment essential to the testing and data analysis of materials and structures. At the present time 20 to 25 faculty and senior researchers, and about 50 graduates and 50 undergraduate students from these Departments work on research projects in the laboratory; laboratory subjects for another 50 graduate and 150 undergraduate students are conducted. It is anticipated that all these numbers will double over the next several years.

The organization of the REMERGENCE Laboratory reflects its interdepartmental character. A faculty committee consisting of all participating researchers is responsible for policy setting. Operating decisions are made by an interdepartmental steering committee chaired by Professor Herbert Einstein of the Department of Civil Engineering. Professor Einstein has provided major leadership to this facility since its conception. Other members of the steering committee are Professor Michael Cleary of the Department of Mechanical Engineering, whose research efforts are central to the development of REMERGENCE, and Professor Baecher, who has worked to integrate the Constructed Facilities Division of the Department and REMERGENCE.

The physical facilities of the REMERGENCE Laboratory are located in the basement and on the second and third floors of Building 1. A total of approximately 16,000 sq. ft. is available. The laboratory consists of specimen preparation rooms, a teaching laboratory, a heavy testing laboratory for geotechnical and structural tests, a light testing laboratory for geotechnical and structural tests, and a soil mechanics laboratory.

Equipment for the facility has been made available from the Mining and Mineral Resources Research Institute (U.S. Department of Interior), Department of Defense, Houston Instrument, Data Instrument, Data Precision, Mettler Instrument, Fairchild, Fluke, and Genisco. Also, MIT resources have been used for equipment and needed space renovation. Of special note was the acquisition of a centrifuge during this past year through support from the Department of Defense and through the efforts of Professor Robert Whitman.

Among the activities being conducted under the aegis of REMERGENCE are segmental bridges, rock mass resistance, underground fracturing, behavior of confined concrete in cyclic compression, metals and
polymers, piezocone development, behavior of refractories under high temperature and pressure, analytic and physical models of ice-structure interaction, pile bearing capacity studies, rock caverns and earth sheltered housing.

In the future, a number of areas will be pursued. The areas of instrumentation, automation and development of new materials and structures are prime targets for joining analysis and experiment. Some particular areas that we expect to focus on in the future are: Automation and Robotics in Construction and Mining, Combined Structural Elements, and Infrastructure Research. The REMERGENCE Laboratory will continue to be a major focus of activity in the host departments. It represents a major commitment of the Institute, and substantial internal and external resources will be devoted to its development.

3. The New England Surface Transportation Infrastructure Consortium

Under the leadership of the Department of Civil Engineering and the Center for Transportation Studies, MIT is developing a New England Consortium to address regional transportation issues and, in particular, those concerned with infrastructure questions. The Consortium will be composed of the six state Departments of Transportation in New England, the six New England state universities, and MIT. The idea is that by pooling financial and intellectual resources, a critically sized program, not supportable by any of the New England states working independently, can be established. Further, problems of regional interest can be effectively and efficiently addressed. The Consortium will merge the academic resources of the region with the engineering experience of the Departments of Transportation to undertake a three-pronged program of:

1. Research, development and demonstrations
2. Education and training
3. Technology transfer and information dissemination

Thus far, support has been provided to MIT by the six New England states to consider issues of program design and identification of initial projects for implementation. The two high priority areas identified for the initial effort are:

1. Design and construction issues associated with rapidly deteriorating concrete bridge decks throughout the region.

2. Issues associated with the need to develop a regional permit policy to deal with oversize and overweight trucks engaged in interstate travel.

Substantive work will begin this next year in both areas. Ultimately, a broader program deriving support not only from the New England states, but also from the Federal government, foundations, and private industry will be developed.

This program is the first of its kind in the United States in the transportation area in pulling together resources from various state and academic resources. It has the potential for providing innovative and cost-effective research programs. The leadership in developing this program has been provided by Mr. Humphrey, and Professors Daniel Roos, Moavenzadeh, and Sussman.

Resource Development

Mr. George Macomber, President of the Macomber Construction Company, endowed two career development professorships in the construction area, one of which is designated for the Department of Civil Engineering. Dr. Alexander Slocum, a new assistant professor of Civil Engineering and an expert in construction robotics, has been named the first such chair holder.

The Union Pacific Foundation renewed its support of the Department's programs for an additional three years. The Shell Foundation continued its support of graduate education. The Exxon Foundation continued its support of our program in construction management.

The Computer Aided Design Systems Facility was dedicated on May 7, 1985. This facility, managed by Professor Logcher, was made possible by substantial gifts of hardware by Apollo Computer, Inc. and software and operating funds from Louis Berger International. Mr. William Poduska, President and Chief Executive Officer of Apollo Computer, Inc. and Dr. Louis Berger, founder and Chairman of Louis Berger International, moving forces behind the facility, both attended the dedication which was highlighted by talks given by Dr. Charles Eastman, President, Formative Technologies, Inc. and Professor Richard Zippel of the Department of Electrical Engineering and Computer Sciences at MIT.

Hardware for the facility donated by Apollo Computer, Inc. include two high resolution graphical workstations, which are powerful single user computers with one-and-one-half Mbyte of memory, and one Apollo file server/computer server of similar capabilities. These computers are networked together and to other computer facilities on campus. Software provided for the facility by Louis Berger International include structural and highway design packages and the CANDID drafting and
graphical data base system. Also, Autotrol has donated an Autotrol System 5000 for educational use. This facility is being used to provide students with experience in computer aided design and drafting and in how to adapt design and drafting systems to specific situations. It will also be used for research in computer-aided preliminary design and in knowledge based data structures for design coordination.

This past year MIT signed a three-year agreement with the Korean Institute of Construction Technology (KICT) for a collaborative program of research and education. KICT is a non-profit organization funded by the Korean government and the Korean construction industry. Topics of initial research will include construction management, computer-aided design, and energy supply and conservation for large housing programs. MIT's participation in the agreement is being directed by a steering committee consisting of: Professor Fred Moavenzadeh, Director (CCR&E); Dr. Leon Glicksman, Director of the Program for Energy Efficient Buildings and Systems in the Mechanical Engineering Department; and Mr. Michael Joroff, Director of the Laboratory for Architecture and Planning in the School of Architecture as Committee Chairman. In addition, the KICT joined the CCR&E Construction Industry Affiliates Program.

The firm of Symmes, Maini, and McKee Associates endowed the Mullin lectureship to honor the memory of Richard L. Mullin, a distinguished architectural engineer who was a principal in the firm. The purpose of this annual lecture is to explore the relationship between engineering and architecture. The first lecture in this series is described in the Seminars/Program section of this report.

Professor Slater's project on "Computer-Aided Teaching in Structural Design" was among the largest supported by MIT's Project Athena and also is the subject of intensive fund-raising activity.

Faculty/Staff

The following faculty members were promoted during this past year. Dr. Baecher and Dr. Oral Buyukozturk to Full Professor; Dr. Shyam Sunder and Dr. Victor Li to Associate Professor, all effective July 1, 1985.

The Department continued its vigorous searches for first-rate people to join our faculty. In this coming academic year, four new assistant professors will join the Department. They are Dr. Michael Celia in the groundwater area, Dr. Sue McNeil in transportation systems analysis, Dr. Duvvuru Siram in the area of computer-based expert systems, and Dr. Alexander Slocum in the area of construction robotics. Ms. Sandra Hull, who is completing her doctorate at MIT, will join the Department as a lecturer for the 1985/86 academic year. Dr. Kenneth Maser and Ms. Susan Merkel joined the Department as research associates.

During this past year, the Department accepted the resignations of three faculty members: Professor Henry Irwig to enter professional practice, Professor Clifford Winston to join the Brookings Institution, and Professor Erik Vanmarcke to accept a position at Princeton University. Dr. Robert Martin, senior research associate, resigned to pursue new technical areas.

This year Professor Roos was named the director of the new Center for Technology, Policy and Industrial Development and as the Japan Steel Industry Professor. He joins Professor Donald R.F. Harleman, Ford Professor of Engineering, Professor Eagleson, Edmund K. Turner Professor of Civil Engineering, and Professor Moavenzadeh, William E. Leonhard Professor of Engineering as chaired senior faculty in the Department.

The Department is pleased to note that Professor Frank E. Perkins will continue as Dean of the Graduate School on a half time basis, allowing his active participation in the educational and research programs of the Department.

Professor Ann F. Friedlaender, a jointly appointed faculty member in the Department of Civil Engineering and the Department of Economics, was named Dean of the School of Humanities and Social Science. She stepped aside from her duties as Head of the Department of Economics to take on these new responsibilities.

Professor Whitman became undergraduate officer of the Department effective July 1, 1984. He replaced Professor Marks, who served in that capacity with distinction and imagination for four years. Professor Marks stepped aside to focus on new research initiatives in the construction area. Professor Whitman, together with Professor Baecher, Head of CFD; Professor Bras, Head of WREE; Professor Wilson, Head of TSD; Professor Moavenzadeh, Director of CCR&E; Professor Ladd, Graduate Admissions Officer; Professor Morel, Graduate Officer; Mr. Trond Kaalstad, Senior Administrative Officer; and Professor Sussman, Head of the Department, form the Department Council, which considers matters of Department policy, resource allocation and faculty development, and advises the Department Head on issues facing the Department.
A number of our faculty published major texts during the past year. Professor Bras co-authored "Random Functions and Hydrology". Professor Yosef Sheffi authored "Urban Transportation Networks". Professor Morel authored "Principles of Aquatic Chemistry". Professor Moavenzadeh co-authored "Transportation, Energy, and Economic Development - A Dilemma in the Developing World". Professor Roos co-authored "The Future of the Automobile". The Department continues to encourage our faculty to produce texts of major importance to the field, and we recognize the substantial professional and personal commitment that such efforts represent. We take great pride in these accomplishments of our colleagues.

Several faculty members were on sabbatical leave. Professor Harleman was a Rockefeller Foundation Residential Scholar at the Villa-Serbelloni-Bellagio Study Center at Lake Como in Italy. He worked on a textbook and on new research directions. Professor Eagleson worked on a variety of new research initiatives. Professor Sheffi worked with several transportation companies affiliated with the Center for Transportation Studies and developed a number of new research thrusts. Professor Madsen was awarded a fellowship by the Japan Society for the Promotion of Science to visit the University of Tokyo, Tokyo Institute of Technology, and a number of other organizations and universities in Japan and worked on developing new research directions.

Professor Eagleson is the president-elect of the American Geophysical Union. He will assume the presidency of this organization in 1986. Also he presented the Chester C. Kisiel Memorial Lecture at the University of Arizona on the topic, "The Emergence of Global Scale Hydrology".

Professor Whitman serves as president of the Earthquake Engineering Research Institute.

Professor Ladd has been designated as the Terzaghi Lecturer for the ASCE meeting to be held in Boston in October 1986. He joins Professor Emeritus Lambe and Professor Whitman in being so honored in this exceptional manner by the geotechnical community.

Professor Morel was elected chairman of the 1986 Gordon Research Conference on "Environmental Sciences: Water".

Professor Sallie Chisholm served on a special MIT committee to examine the relationship between the undergraduate programs in humanities and social science and engineering. This committee's work led to a major two-day meeting on this topic held at Woodstock, Vermont, in which she and Professor Sussman were participants.

A paper authored by Mr. A. M. Salhotra, a graduate student in Civil Engineering, Dr. Adams and Professor Harleman on "Evaporation and Stratification Study for the Dead Sea" received the award for Best Paper from outside the host country at the Fourth Congress of the Asian and Pacific Regional Division of the International Association for Hydraulic Research.

Professor Chiang Mei received the Department's Effective Teaching Award for the second time, an extraordinary continued record of excellence in the classroom. Also, Professor Mei and Mr. A. E. Myrett were awarded the T. K. Hsieh Award from the Institution of Civil Engineers in England for a paper entitled, "Earthquake Induced Stresses in a Poro-Elastic Foundation Supporting a Rigid Structure".

Dr. Germaine, director of the Geotechnical Laboratory, received the Graduate Student Council Teaching Award in Civil Engineering.

Under the leadership of Professor Logcher, the Boston Society of Civil Engineers formed a new group in "Engineering Management". Professor Logcher will chair this group.

Mr. Carl Martland was the chief organizer of the 25th Annual Meeting of the Transportation Research Forum held in Boston.

Professor Baecher delivered a keynote paper on "Intelligence for Construction Robots" at the NATO Conference on Advanced Robotics in Como, Italy.

Professor Lynn Gelhar gave a series of invited lectures at a Groundwater Research Workshop sponsored by CSIRO and the University of Western Australia in Perth, Australia.

Professor Mohsen Baligh gave an invited lecture on "Interpretation of Penetration Tests" to the Italian Society of Civil Engineers in Milan, Italy.

Professor Sussman delivered a keynote address on "New Models for Civil Engineering Undergraduate Education" at the ASCE Engineering Education Conference at Ohio State University, Columbus, Ohio.
Professor Ladd gave the luncheon address at the ASCE ARCTIC '85 National Conference on "Civil Engineering in the Arctic Offshore" in San Francisco. He spoke on "Research and Educational Activities at MIT Related to the Design of Offshore Structures". Professor Shyam Sunder was active in the organization of this conference and presented a paper entitled, "Sea Ice Indentation Accounting for Strain-Rate Variation". Also, at this meeting Professor Daniele Veneziano presented a paper entitled, "Spectral Analysis of Ice Charts".

Professors Logcher, Slater, and Baecher participated in the NSF Workshop on "Computers in Construction" held at Northwestern University.

The following students were recognized:

Mr. Peng Chong Sien was the winner of the Richard Lee Russel Award, given to an outstanding senior in Civil Engineering who plans to continue on to graduate school.

Ms. Kim Roddis won the student paper award presented at the International Bridge Conference in Pittsburgh. Her paper is entitled, "Stress Ribbon Bridges: An Innovative Structural Form".

Dr. Roger Burke was named the winner of the Lorenz G. Straub Award for an outstanding thesis in hydraulic engineering. His thesis entitled, "Free Surface Flow through Marsh Grass", was supervised by Professor Keith Stolzenbach. Dr. Burke is a graduate of the MIT/Woods Hole Joint Program in Oceanographic Engineering.

Mr. Richard Littlefield was awarded the Steinberg Prize, given to an undergraduate student for academic achievement and demonstrated interest in construction management.

The Department was pleased to have the following colleagues as visiting faculty during the past year:

Professor Stella Dafermos  
Brown University

Professor Ian Fisher  
University of New England, Armidale, New South Wales, Australia

Professor Uwe Pape  
Technical University of Berlin, Germany

Professor Uri Shamir  
The Technion, Haifa, Israel

Colonel LaVon Linn, a major benefactor of the Department, died on May 4, 1985. Colonel and Mrs. Linn supported the Department's activities through their endowment of the Gilbert E. Winslow Career Development Chair for junior faculty and the Winslow Scholars program for undergraduate students. The Department expresses its sympathy to Mrs. Linn and sincere appreciation for the deep interest Colonel and Mrs. Linn showed in the Department for many years.

Visiting Committee

The Corporation Visiting Committee was not scheduled to meet during the past year. A meeting is planned for the next academic year. The Department Head met on several occasions with Dr. Aldrich, Head of the Visiting Committee, to discuss Departmental matters. Also, a number of Visiting Committee members participated in the Alumni Colloquium and other Department activities, including the dedication of the Computer Aided Design Systems Facility and the Advisory Committee of CCR&E.

Completing their terms as Visiting Committee members on June 30, 1985, are Dr. Rolf Eliassen and Mr. Griff Lee. The Department thanks both these members for their guidance and helpful advice over the past several years.

The Department welcomes the following new member, effective July 1, 1984:

Dr. Brian J. Watt, President  
Brian Watt Associates, Inc., Houston, Texas

Seminars and Programs

The faculty of the Department participated in a variety of programs and seminars at MIT during the past year. Among the most notable are the following:

During the Independent Activities Period (IAP) the Department sponsored a series of lectures on "The Impact of Computers on Future Civil Engineering Practice", led by Professor Logcher. Professor Baecher
organized a series of seminars on robots in construction. Also during IAP, Professors Slater and Gibson organized a design contest in which students built a tower from a kit of materials. Students from across the Institute developed design concepts, built models, and tested their structures to failure in Lobby 10 before several hundred interested observers.

Dr. Aldrich, Chairman of Haley & Aldrich, Inc. spoke at the annual Student/Faculty Dinner on "A Reflection on the First Fifty Years of Civil Engineering at MIT."

Professor Stolzenbach was the co-coordinator of the 1985 MIT Sea Grant Lecture/Seminar on Ocean Disposal of Public Wastes. This well attended two-day meeting highlighted a number of technical issues and public policy questions.

Professor Marks organized and led a two-day National Science Foundation sponsored conference on "Analysis Methods in Infrastructure Repair and Rehabilitation" at MIT's Endicott House.

Under the joint auspices of the Center for Scientific Excellence in Offshore Engineering and the Sea Grant Program at MIT, a workshop on "Breaking Processes of Ice Plates" was organized. Professors Connor and Shyam Sunder gave presentations, and Professor Li gave one of the keynote addresses.

Professor Whitman organized and chaired a special workshop on liquefaction sponsored by the National Science Foundation held at MIT's Endicott House. This workshop attracted a distinguished international group of participants.

The Department hosted a public meeting organized by the Massachusetts Department of Public Works to discuss the reconstruction of the Harvard Bridge, a distressed structure which connects Cambridge and Boston at Massachusetts Avenue. This facility has profound impact on the MIT community and, accordingly, an overflow crowd of 250 people attended this hearing.

A number of TSD faculty, including Professors Roos, Sheffi, Kocur, and Sussman participated in the Center for Transportation Studies Transportation Forum. The theme of this meeting was "Transportation: Changing Boundaries and Relationships".

The Sam J. Mathis Lecture was held on October 11, 1984. Professor Andrew N. Schofield of Cambridge University in England spoke on "Cam-Clay Flow and Liquefaction".

The first Richard L. Mullin Lecture was held on October 25, 1984. Mr. Ezra Ehrenkrantz, President of The Ehrenkrantz Group in New York, gave a talk on "Architectural and Engineering Strategies for the Building Industry".

The James A. Henderson Memorial Lecture was held on November 15, 1984. Mr. Robert R. Kiley, Chairman of the Metropolitan Transportation Authority in New York, spoke on "The Subways: New York City's Greatest Public Work".

JOSEPH M. SUSSMAN
Department of Electrical Engineering and Computer Science

A major event in the Fall was the vote by the MIT faculty to enable the Committee on Undergraduate Admissions and Financial Aid to limit admission to MIT of students interested in majoring in Electrical Engineering and Computer Science if certain target figures are not met. The targets are: 350 sophomore majors in EECS in Fall, 1984; 310 sophomore majors in Fall, 1985; and 270 sophomore majors in Fall, 1986 and beyond. We are pleased to report that as a result of much effort on the part of many people at the Institute, we appear to be coming very close to the target figures. As a result, the Committee may never have to impose any limitations.

In retrospect the decline in sophomore majors in EECS in the Fall, 1984, can be accounted for by a sizable increase in the number of majors in the Sloan School's Information Systems program, the Department of Materials Science and Engineering's emphasis on electronic materials and the Psychology Department's Cognitive Science program. During 1984-5, the Department worked with the Mathematics Department to introduce a new program, entitled Mathematics with Computer Science. We also worked with the Physics Department to introduce an option in Physics, called Physics with Electrical Engineering. The Physics option appears quite popular with the current freshman class. It now appears that in large part because of all these programs the number of EECS sophomore majors in Fall, 1985, will likely be close to the target figure of 310.

Notwithstanding the decreasing input noted above, total undergraduate enrollments in EECS were, as expected, the largest in our history. We handled it with grace with additional support from our colleagues, affiliated both with MIT and elsewhere. Several faculty members who taught sections of our undergraduate subjects this past year came from other MIT departments, namely: Urban Studies and Planning, Aeronautics and Astronautics, and Physics. In addition, we obtained a five year grant at $50 thousand per year from the GenRad Foundation for support of visiting professors. Three visiting faculty members taught EECS subjects this past year with the partial support from this grant.

A loyal alumnus and his wife pledged to support a term professorship at $100 thousand per year. This chair, called the Distinguished Professorship in Electrical Engineering and Computer Science, was given to Professor Richard B. Adler, Associate Head of the Department and a long time leader in the Department in education and in research on semiconductors. The bulk of the funds in the chair were distributed to some of the Department's faculty for the support of their research.

The Hewlett-Packard Co. announced this year a $50 million program of equipment gifts to universities in support of education using Artificial Intelligence techniques. The Department is to receive the first such gift entailing approximately $4.5 million worth of H-P computers. The computers will be used to support the laboratory in our common core subject, 6.003 Signals and Systems. The new laboratory projects will involve the use of the language SCHEME taught in 6.001 Structure and Interpretation of Computer Programs.

The Tektronix Company has donated to EECS $400 thousand worth of oscilloscopes. These 90 oscilloscopes are part of a program to replace all 200 of the oscilloscopes used in our undergraduate laboratories with new ones of a single type. The new oscilloscopes are expected to be far easier to maintain over the years.

Our annual garden party at Endicott House in May, 1985 was a special event. The Department's history book, "A Century of Electrical Engineering and Computer Science at MIT, 1882-1982," written by Karl L. Wildes and Nilo A. Lindgren, and published by the MIT Press, was officially unveiled that day. The book represents the culmination of 25 years of research by Professor Emeritus Wildes and intensive effort by EE alumnus and writer Lindgren during the past several years. President Paul E. Gray wrote the preface to the book.

The first in the Department's new series of undergraduate texts, co-published by the MIT Press and McGraw-Hill, appeared in 1984. This is the text for our popular course, 6.001, Structure and Interpretation of Computer Programs, taught by Professors Harold Abelson and Gerald Sussman. The text has received wide critical acclaim. At least two other texts in this series are expected to be published in the coming year.

Much of renovation of Building 39 for our new VLSI facility was completed in the past year. Most of the faculty and students have moved into the building. We anticipate the facility to be fully operational by the coming Fall. Dedication is planned for the Corporation meeting in December, 1985.
Enrollment of undergraduates averaged 1,150 in 1984-85, with about 66 percent in the Electrical Engineering Program and 34 percent in the Computer Science Program. The total represents an increase of about 20 students from the previous year. As a result of a variety of efforts aimed at reducing the number of our undergraduates, 369 sophomores were enrolled in the Department this year. This was down from a projection of 420 students. Initial estimates indicate that a sophomore class of 320 students will enter the Department in the Fall of 1985. We hope to reduce further to about 270 sophomores in the Fall of 1986.

The Accreditation Board for Engineering and Technology accredited the Computer Science program for six years and the Electrical Engineering program for three years. There was concern about insufficient explicit emphasis on engineering design in the latter program and steps are being taken to deal with this concern when the program comes up for review in 1987.

The following prizes and awards were won by our students. The Ernst A. Guillemin Prizes for outstanding S.B. theses in Electrical Engineering were awarded to Ashraf S. Alkhairy of Riyadh, Saudi Arabia (first prize), Andrew A. Berlin of Monsey, NY (second prize), and Glenn Weinreb of Charlottesville, Va (third prize). Honorable mention went to Curtis Tsai of St. Paul, MN, and Mark Wu of Fresno, CA. The William A. Martin Memorial Prize for the outstanding thesis in Computer Science was won by Juan R. Loaiza of Clearwater, FL (first prize), and Philip C. Nelson of Mamaroneck, NY (second prize). The Computer Systems Thesis Prize was presented to Larry W. Allen (first prize), and John L. Romkey of Lincoln, ME (second prize). The George C. Newton Prize for the best undergraduate laboratory project was awarded for the first time this year. The prize was awarded jointly to Stephen C. Phillips of Norwood, MA, and Theodore Tewksbury of Peterborough, NH. Susan Pitts of Brunswick, ME, was the winner of the 6.004 design contest.

The following special scholarships were awarded to our students: the General Motors Scholarships for academic excellence were awarded to Paul Ducknowski of Staten Island, NY, and to Benjamin M. Gordon of State College, PA. The Kodak Scholarship for academic excellence was awarded to Josef Shaoul of Abidjan, Ivory Coast. Donald E. Bossi of Endwell, NY, was awarded the Henry Ford II Scholarship. Ondria G. Jaffe received an Award from the Association of MIT Alumnae (AMITA) for the highest level of academic excellence by a female undergraduate.

Stephanie L. Scheidler was awarded the Karl Taylor Compton Award for outstanding contributions in promoting high standards of achievement and good citizenship within the MIT community. Mr. Oren Michels was awarded the Louis Sudler Prize in the Arts.

In September, 1984, there were 618 graduate students enrolled in the Department. Of this number 205 were newly admitted. About 20 percent of the total were foreign nationals. The Department supported 256 Research Assistants, 114 Teaching Assistants, and awarded 38 fellowships. In addition, there were 30 National Science Foundation Fellows and 15 Hertz Fellows. The remaining students had industrial or foreign government support or were using their own funds.

During 1984 the Department awarded the following graduate degrees: 173 masters of science, 22 electrical engineers, and 40 doctorates.

A number of Departmental awards were made to graduate students for excellence in teaching. Jeffrey K. Bounds, Silvano A. Brewster, Thrasvoulos N. Pappas, and Gill Pratt were given the Frederick C. Henrie, III Award, an award funded by Proctor and Gamble; the Carleton E. Tucker Award was won by Ian R. Webb; and the Harold L. Hazen Award, funded by an anonymous donor, was won by Jennifer R. Melcher. Promotions to Instructor-G were made for graduate students Robert W. Baldwin, Leo F. Casey, and Robert H. Enders.

The Spring of 85's 216 sophomore applicants represented about 3 percent more of their Course VI class than those from the class of '87 applying a year ago - indicating a continuing strong student interest in the Program. The demand from participating companies also remains high and many inquiries from companies across the nation desiring to join the Program continue to come in. Of those students applying 94, or over 43 percent, were finally selected to join.

This year, for the first time, the Department was forced to set quotas in advance on the numbers of new students each company could select. This was in line with the plan to bring the total enrollment in VI-A nearer to 250 which is considered a reasonable level for proper supervision by the present faculty. This
was an extremely painful task; but over the past five years relying on the economy and voluntary cutbacks just hasn't worked.

The divestiture of the AT&T Co. divided Bell Laboratories into two entities: AT&T Bell Labs. and Bell Communications Research ("Bellcore"). Discussions last summer and fall led to dividing Bell's VI-A quota between the two, with Bellcore taking two new students to start.

One deletion from the Program is RCA's Astro-Electronics Division which has taken students since about 1967. Their VI-A experience has been acknowledged as positive, but they feel that their match to the interests of VI-A students is not adequate to continue beyond their current students, who will complete all their assignments. RCA's Sarnoff Laboratory will however continue its VI-A affiliation.

The percentage of VI-A seniors continuing on to the graduate phase of the Program remains high at over 86 percent, or a total of 76 students; 26 were given Regular Admission while 50 received the SM-only restricted admission, special to VI-A.

Our VI-A graduates constitute an extremely loyal alumni group. John A. Tucker, VI-A's Director for the past sixteen years, has fostered that camaraderie through his continuing personal relations with many of these graduates over the years, along with numerous articles written for the "Notes" section of Technology Review. This spring, at Technology Day ceremonies on June 7th, John's accomplishments were acknowledged by his being elected an "Honorary Member" of the M.I.T. Alumni Association, a distinction given only 92 others since its authorization in 1897.

RESEARCH

Most research of our faculty is performed in interdepartmental laboratories. We estimate the total FY85 research volume on projects of which our faculty or research staff members are in charge to be over $46 million, of which only $3.6 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>7.4</td>
</tr>
<tr>
<td>Laboratory for Computer Science</td>
<td>11.4</td>
</tr>
<tr>
<td>Laboratory for Electromagnetic and Electronic Systems</td>
<td>2.9</td>
</tr>
<tr>
<td>Laboratory for Information and Decision Systems</td>
<td>2.4</td>
</tr>
<tr>
<td>Research Laboratory for Electronics</td>
<td>7.9</td>
</tr>
<tr>
<td>Plasma Fusion Center</td>
<td>10.5</td>
</tr>
</tbody>
</table>

In addition to the laboratories noted above, faculty research is also performed in other interdepartmental 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 Program and MIT Stroboscopic Light Laboratory are departmental in organization and therefore report below the highlights of their research for the past year.

MIT MICROSYSTEMS PROGRAM (Professor Paul L. Penfield, Jr.)

The MIT Microsystems Program is an interlaboratory, interdepartmental enterprise, started in about 1978, and administered by the Department. This year the level of research effort exceeded $7.4 million and the technical areas of interest include electronic materials, submicron structures, integrated-circuit processing and devices, design automation, architecture, and VLSI theory. Virtually all of the research is reported separately by the various other laboratories associated with the Department, but some highlights deserve special mention here.

The new MIT Microsystems Technology Laboratories occupying all of Building 39 are near completion. This new facility will support research in both VLSI and submicron structures technologies.
The Semiconductor Research Corporation, a funding agency supported by industry, was reported last year as sponsoring a program of research in Multi-Layer Integrated Circuit Technology at MIT, with nine related projects, many dealing with low-temperature fabrication steps. In June 1985, the program was reoriented in a major way to focus on processing steps useful for high-speed high-precision analog applications.

One component of a VLSI design system is a program to automatically place and route subsystems on a chip. The PI (Placement and Interconnect) program, under development at MIT for several years for this purpose, has now reached a state of maturity and is being further developed in industry.

During this year MIT achieved the record for the world's shortest MOSFET when devices with channel lengths of 750 Angstroms were made and evaluated. Earlier this year the world's first surface-super-lattice device incorporated in a MOSFET was made.

A novel memory device was invented here, that allows a modest amount of nonvolatile memory to be put on a chip. The unique aspect is that a standard NMOS or CMOS process is used -- no special processing steps. The programming of the memory, which is done after manufacture using ultra-violet light, can be repeated any number of times.

Stroboscopic Light Laboratory (Professor Harold E. Edgerton)

Activities of the Laboratory this year revolved primarily about experimental projects in the subject 6.163, which is taught by Charles Miller and enrolls about 25 students per semester, about half of whom are in Course VI.

Professor Edgerton's 1979 text ELECTRONIC FLASH, STROBE (MIT Press) and the hour-long NOVA program tape "Edgerton and His Incredible Seeing Machine" deal with techniques and the development of electronic flash, and form the core material for the subject.

The Laboratory continues to support a significant number of SB theses each year, some of which are extensions of 6.163 projects.

FACULTY

Faculty promotions this year included Jeffrey H. Shapiro and Donald E. Troxel to full professor; and Jeffrey H. Lang, Terry P. Orlando, Richard E. Zippel, and Victor W. Zue to associate professor.

Richard B. Adler, associate head of the Department, was named the first Distinguished Professor of Electrical Engineering and Computer Science in recognition of the donor's deep interest in education and semiconductor electronics; and in keeping with the ITT Career Development Chair which supports young faculty working at the forefront of computer technology, David K. Gifford was appointed ITT Career Development Assistant Professor of Computer Science and Engineering for two years; Barbara H. Liskov was named Nippon Electric Company (NEC) Professor of Software Science and Engineering and is the first occupant of the Chair which was established in 1982 by NEC Corporation of Tokyo; Frederic R. Morgenthaler was named Cecil H. Green Professor of Electrical Engineering for two years, which will allow him to further develop new directions in research and education; and the first occupant of the new Keithley Chair will be Martin F. Schlecht as Joseph F. and Nancy P. Keithley Career Development Assistant Professor of Electrical Engineering which will enable him to pursue his recently developing interest in integrated circuits.

Joining our faculty this year were Rodney A. Brooks, formerly an assistant professor at Stanford University and, for two years, a research scientist in the Artificial Intelligence (AI) Laboratory at MIT, now Assistant Professor of Computer Science and Engineering; James G. Fujimoto, who received a Ph.D. from MIT and was previously a research associate in the Department, now Assistant Professor of Electrical Engineering; William E.L. Grimson, formerly a research scientist in the AI Laboratory at MIT, now Assistant Professor of Computer Science and Engineering; Hae-Seung Lee, who received a Ph.D. from the University of Pennsylvania, now Assistant Professor of Computer Science and Engineering; John N. Tsitsiklis, who received a Ph.D. from MIT and was previously Acting Professor of Electrical Engineering at Stanford University, now Assistant Professor of Electrical Engineering; and William E. Weihl, who received a Ph.D. from MIT, now Assistant Professor of Computer Science and Engineering.

A number of faculty achievements during the year deserve special mention: Robert C. Berwick, Assistant Professor of Computer Science and Engineering, was this year's recipient of the Harold E. Edgerton Award which is bestowed on a junior faculty member at MIT for distinction in teaching, research, and scholarship; H. Kent Bowen, Ford Professor of Engineering, was named director of the newly established Manufacturing Systems Program which is designed to provide focus and coherence in the area of materials processing and manufacturing and foster the development of the emerging field of manufacturing systems engineering and
management; Gordon S. Brown, Institute Professor, Emeritus, was awarded an Institute of Electrical and
Electronics Engineers (IEEE) Centennial Medal and Certificate for his valued contributions and service to
the IEEE and to the profession; Mildred S. Dresselhaus, Abby Rockefeller Mauzé Professor of Electrical
Engineering and Physics, has been elected to the National Academy of Sciences, and also elected to the
board of directors of the American Association for the Advancement of Science (AAAS); and Peter Elias,
Edwin S. Webster Professor of Electrical Engineering, was voted chairman-elect of the Engineering Section
of the AAAS; Pierre A. Humbel, Associate Professor of Electrical Engineering, was chosen a Centennial
Young Engineer and presented with a key by the IEEE for demonstrating sound understanding of the evolving
technologies in his field and showing promise in applying those technologies for the improvement of society; Eric P. Ippen, Professor of Electrical Engineering, was elected to the National Academy of
Sciences, and also to the National Academy of Engineering for his pioneering contributions to nonlinear
optics in optical waveguides and ultrashort-optical-pulse-generation techniques; two members of the Department were elected Fellows of IEEE: Jørn A. Kong, Professor of Electrical Engineering, for contributions to electromagnetic theory, microwave remote sensing, and education; and Gunter Stein, Adjunct Professor of
Electrical Engineering, for leadership in making practical the application of modern control theory;
Professor Kong was also awarded the 1985 Graduate Student Council Departmental Award for excellence in
teaching; Raphael C. Lee, Assistant Professor of Electrical Engineering and a MacArthur Fellow, has been
included in the list of "America's Top 100 Young Scientists" compiled by Science Digest for its year-end
issue (also included was Daniel Hillis, a graduate student in the AI Laboratory); Charles E. Leiserson
and Tomás Lozano-Pérez, both Associate Professors of Computer Science and Engineering, received Presidential
Young Investigators Awards, established by the White House, through the National Science Foundation,
to help assure the vitality of American research universities for the development of the next generation
of technical leaders; Jerome Y. Lettvin, Professor of Electrical and Bioengineering and Communications
Professor of Electrical Engineering, was awarded a Senior Vinton Hayes Fellowship for his work in biological communication; Barbara H. Liskov, NEC Professor of Software Science and Engineering, was appointed to the Board of the Institute of Graduate
Studies National Advisory Committee; James R. Melcher, Stratton Professor of Electrical Engineering and
Physics, and previously associate director of the Laboratory for Electromagnetic and Electronic Systems
(LEES), assumed the directorship of LEES; two-year IBM Faculty Development Awards for untended faculty
were granted to Silvio Micail and Christopher J. Terman, both Assistant Professors of Computer Science and
Engineering, and to Charles G. Sodini, Assistant Professor of Electrical Engineering; Paul L. Penfield, Jr.,
Professor of Electrical Engineering and Computer Science, became director of the recently completed Microsystems Center located in Building 39; Institute Professor, Emeritus, Walter A. Rosenblith was elected vice president of the International
Council of Scientific Unions for four years; Jerome H. Saltzer, Professor of Computer Science and
Engineering, was appointed technical director of Project Athena; and Claude E. Shannon, Donner Professor
of Science, Emeritus, was elected to the National Academy of Engineering for devising a mathematical
theory of communication, now known as information theory; several books were forthcoming during the year
and merit recognition: Structure and Interpretation of Computer Programs, an introductory text by Associate
Professor Harold Abelson and Professor Gerald J. Sussman, with Ms. Julie Sussman, inaugurating the MIT
Electrical Engineering and Computer Science Series, and published by the MIT Press; The Grammatical Basis
of Linguistic Performance, which considers an explanatory theory of human parsing and language acquisition,
by Assistant Professor Robert C. Berwick, with Ms. Amy S. Weinberg, a graduate student in the Department of
Linguistics and Philosophy, and published by the MIT Press; Design and Analysis of VLSI Circuits, co-authored by Assistant Professor Lance A. Glasser and D.W. Dobberpuhl of Digital Equipment Corporation, and published by Addison-Wesley; Professor Hermann A. Haus' Waves and Fields in Optoelectronics, an introductory text in the Prentice-Hall solid state electronics series, published by Prentice Hall; The AI Business, which deals with commercial uses of artificial intelligence, co-edited by Professor Patrick H. Winston, with Ms. Karen A. Prendergast, and published by the MIT Press; and A Century of
Electrical Engineering and Computer Science at MIT, 1882-1982, a chronicle of change and growth in electrical
engineering and computer science at the Institute, co-authored by Professor, Emeritus, Karl L. Wildes
and Nilo A. Lindgren (EE'48), and published by the MIT Press.

The Department was pleased to welcome the following visiting faculty, two of whom were supported by GenRad,
Inc. in a program for visiting faculty involved in teaching departmental undergraduate subjects: Paris C.
Kanellakis, GenRad Visiting Assistant Professor of Electrical Engineering and Computer Science, on leave
from Brown University, who gave guest lectures fall term in 6.852 Distributed Algorithms and co-lectured
6.035 Computer Language engineering spring term; and José M.F. de Moura, GenRad Visiting Associate Professor of Electrical Engineering and Computer Science, on sabbatical leave from the Institute Superior Técnico in Portugal, who taught sections of undergraduate core subjects and conducted research in system
theory and signal processing; Lan Jin, Visiting Professor of Computer Science and Engineering, on leave
fall term from Tsinghua University in China, who taught sections of 6.004 Computation Structures and
contributed to research in advanced computer architecture, microprocessor systems, and computer networks;
and Jorge Mescua, Visiting Associate Professor, on sabbatical leave from the University of North Carolina
at Charlotte, who lectured 6.061 Modeling and Analysis of Electromechanical Devices fall term and also
conducted research in performing electro-optic field and space charge mapping measurements in dielectric
fluids.

Department faculty who were away during the year included Professor Dimitri P. Bertsekas, on sabbatical
spring term, to give lectures at the University of Athens and the University of Illinois; Professor Louis D.
Braida, on sabbatical for the academic year to work with the continuous speech recognition group at
IBM Thomas J. Watson Research Laboratory; Professor Thomas H. Lee, on extended leave of absence to become director of the International Institute of Applied Systems Analysis in Austria in order to concentrate his efforts on energy, agriculture, population, and environmental systems analyses; Professor Hermann A. Haus, on sabbatical for the academic year to teach optical electronics at the Technical University of Vienna as a Fulbright Fellow, and, as a visiting scientist, to conduct research in optical communications at AT&T Bell Laboratories and Bell Communications Research, and for part of the year to study integrated optics at the Nippon Telephone and Telegraph Company; Associate Professor George C. Verghese, on leave of absence spring term to work in the area of control and estimation for electrical machine systems at the Technische Universität in Berlin; and Professor Cardinal Warde, on leave of absence for the fall term to teach at the University of California in San Diego, and on sabbatical spring term to work on chapters of a forthcoming book on optical information processing.

Associate Professor Michael Hammer has resigned from a full-time faculty position in order to pursue his business interests, but will continue in the Department as Adjunct Professor of Computer Science and Engineering; Assistant Professor David P. Reed has resigned from the faculty but will retain a Lecturer appointment in the Department.

Professor Joseph C.R. Licklider, who retired after a distinguished career in industry, government, and as a faculty member at MIT, will continue in the Department as a Senior Lecturer.

The Department was saddened by the death of Emeritus Professor John G. Trump, a pioneer in the use of high-voltage energy which led to his seminal work in treating cancer by radiation therapy. Professor Trump, who headed the High Voltage Research Laboratory at MIT until 1980, received posthumously the National Medal of Science, the Nation's highest award for scientific achievement.

JOEL MOSES
INTRODUCTION

The academic year 1984-1985 was a year of solid progress for the Department in its educational and research roles, and in its endowed and other funding. On the undergraduate level, we are pleased by the continuing high number of sophomores electing our Department. In 1982-1983 we reached a low point for recent years with a sophomore enrollment in the mid-twenties. This year it was in the mid-forties and we project a similar number next year. We believe this success has resulted from the continued strengthening of the undergraduate curriculum, the broadening of the Department to include increased emphasis on materials other than metals, and increased faculty involvement in undergraduate teaching and recruiting.

At the graduate level, our new degree program in electronic materials is establishing itself well and serving to attract a strong group of graduate students, a number of whom have selected the Department because of this new degree program. The remaining five degree programs all continue to have high student interest and involvement.

A particularly gratifying development over the last year has been the establishment in this Department of two endowed professorships. The Kyocera Professorship, formed with a grant of one million dollars from the Kyocera Corporation was awarded to Professor W.D. Kingery. The second chair, the John Chipman Assistant Professorship of Chemical Process Metallurgy, was awarded to a new junior faculty member, Professor R. Erik Spjut. This chair has an endowment in excess of $600,000. Approximately one quarter of the funds came from the steel industry in the United States, approximately one quarter from the steel industry outside of the United States; and the remainder came from former students, colleagues, and associates of John Chipman, and from other alumni of this Department. It has been a moving experience for us to see the outpouring of respect and generosity for this great man who led our Department for sixteen years, and who contributed so much to the development of modern metallurgical science. We are also extremely grateful to note the establishment of a new term junior professorship in the area of mechanical metallurgy and composite materials. This has been made possible through a generous grant from Alcoa through Alcoa Laboratories. We now have a vigorous search underway to fill this position.

In last year's annual report it was recorded that a cornerstone of our new undergraduate curriculum "...is a two-tier laboratory sequence, the implementation of which has begun but can be fully completed only after substantial acquisition of new equipment." We are overjoyed to report that the Balfour Foundation has provided a $1 million grant to be paid over a period of approximately three years to permit the acquisition of this needed new equipment. An initial portion of the funds is at hand and acquisition of the equipment will begin this summer. This will make an incalculable improvement in the laboratory experience that our undergraduates will receive.

The Department of Materials Science and Engineering continues to be an outstandingly strong research department. Research volume is approximately $13.4 million per year, supervised for the most part by individual faculty or by groups of faculty. This research is administered through the Department (51%), the Materials Processing Center (28%), the Energy Laboratory (12%), the Center for Materials Science and Engineering (4%), 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 department 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 financial support of industry, and the continued interaction of the Department with industry. Nine of our faculty now hold named chairs, of which four are endowed and five are term. The four endowed chairholders and chairs are: Professor H. Kent Bowen, Ford Professor of Engineering; Professor Merton C. Flemings, Toyota Professor of Materials Processing; Professor W. David Kingery, Kyocera Professor of Ceramics; and Professor R. Erik Spjut, John Chipman Assistant Professor of Chemical Process Metallurgy. The five term chairholders and chairs are: Professor John P. Elliott, AISI Distinguished Professor; Professor Ronald M. Latanision, Shell Distinguished Professor; Professor Donald R. Uhlmann, Cabot Professor of Materials; Professor Samuel M. Allen, ARCO Associate Professor of Physical Metallurgy; and Professor Gretchen Kalonji, Norton Assistant Professor of Materials Processing. Professor Kalonji also continues to hold the prestigious Presidential Young Investigator Award. In addition, two faculty members during this past year held IBM Faculty Development Grants: Professor Terry A. Ring and Professor Gary E. Wnek. Professor Yet-Ming Chiang held a Dupont Faculty Development Grant.

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 John Chipman Chair. Industrial research support for faculty of this Department is handled largely through the Materials Processing Center. This Center, now 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 $5 million of which more than $2 million was from industry.

THE UNDERGRADUATE PROGRAM

A detailed description was given in last year's annual report of the major changes undertaken by the Department in revising its undergraduate program, with the general aims of broadening its offerings in each of the four materials classes, strengthening its laboratories, and attracting more and higher quality sophomores to the Department. In addition to laboratory development, our curriculum development for the undergraduate program during the last year comprised an exhaustive review of subject openings, subject re-scheduling, and modest changes in subjects and subject contents. Major changes were made in the first tier of of our two tier undergraduate laboratory sequence, subject 3.081 "Materials Laboratory". Professor Linn W. Hobbs assumed full responsibility for this laboratory and began the arduous process of introducing new laboratory experiments, particularly experiments having to do with materials other than metals. This development will continue during the coming year as the new equipment is received and installed. Changes in three of our four second tier laboratories were also significant, and more are anticipated next year.

Our combined undergraduate enrollment in Course III, IIIA, and IIIB is projected in the fall to be in excess of 45 students in each of the sophomore, junior, and senior classes. If this projection holds we will have the highest number of undergraduate students in our department's history. The Coop program (Course IIIB) continues to draw a sizable fraction of our undergraduates, and continues to be highly regarded by the students. Approximately 61% of our juniors and seniors are in the cooperative program.

THE GRADUATE PROGRAM

In September 1984 there were 252 graduate students enrolled in the Department, up from 243 the previous year. Both figures constitute new records. Of this number, 88 were newly admitted students; and an additional 22 were admitted in February 1985. As of the fall semester, of the total graduate students in the Department, 71% were supported by research assistantships, 6% by teaching assistantships, and 18% by fellowships. The remaining students relied on their own funds or on outside sources.
Approximately 68% of the graduate students were from the United States, up slightly from the previous year. The students were divided among the Degree Programs in February, 1985, as follows:

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>% of Students</th>
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<tbody>
<tr>
<td>Ceramics</td>
<td>21</td>
</tr>
<tr>
<td>Electronic Materials</td>
<td>16</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>24</td>
</tr>
<tr>
<td>Polymers</td>
<td>10</td>
</tr>
<tr>
<td>Materials Science</td>
<td>13</td>
</tr>
<tr>
<td>Materials Engineering</td>
<td>16</td>
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Our faculty in the polymer area are working closely with faculty from other departments to develop a new "Polymer Program in Science and Technology" (PPST). We are optimistic that this new interdepartmental program will be established in 1986 and believe it will enhance the educational program in polymers of the Institute, and of this Department in particular.

FACULTY

Two new assistant professors joined our faculty this year, Professor Yet-Ming Chiang and Professor R. Erik Spjut. Professor Lionel C. Kimerling, Head, Materials Physics Research, Bell Labs, joined our faculty as adjunct professor. Professor Terry A. Ring and Gary E. Wnek were promoted to associate professors. Professor Samuel M. Allen was granted tenure during this academic year, thereby joining our senior faculty ranks. Professor H. Kent Bowen was appointed the first Director of the Manufacturing and Processing Systems Program and Professor Ronald M. Latanision succeeded him as Director of the Materials Processing Center.

Professor Robert E. Ogilvie retired after twenty-nine years on our faculty, during which time he specialized in X-ray analysis and other materials characterization methods, and in analysis of art and archaeological objects. He will now devote a greater fraction of his time to these efforts at the Museum of Fine Arts. Professor Walter S. Owen has also indicated his intention to retire at the end of this academic year, after ten years in the Department, including eight years as Department Head. We are happy that Professor Owen will continue to conduct research in this Department and otherwise remain active on a part time basis through his appointment as Senior Lecturer (as well as Professor emeritus).

Professor Robert L. Coble received a Humboldt Award for study at the Max Planck Institute, Stuttgart. Professor Morris Cohen received the honorary degree of Doctor of Engineering of the Colorado School of Mines. Professor Thomas W. Eager (while on sabbatical leave serving as Liaison Scientist for the U.S. Office of Naval Research in Tokyo) received the Charles Jennings Memorial Medal of the American Welding Society. Professor John F. Elliott was elected Fellow of the American Association for the Advancement of Science, and Professor Merton C. Flemings received the James Douglas Gold Medal of the AIME. Professor Thomas B. King was awarded the D.Sc. (honoris causa) of the University of Strathclyde. Professor W. David Kingery received the endowed Kyocera Professorship mentioned earlier. Professor Ronald M. Latanision was elected to the National Academy of Engineering and Professor Walter S. Owen received the Graduate Student Council Teaching Award for academic year 1984-1985. Professor R. Erik Spjut received the John Chipman Chair. Professor Harry Tuller was elected a Fellow of the American Ceramic Society. He was also appointed Director of the Crystal Physics and Optical Electronics Laboratory. Professor Ioannis V. Yannas received the "Best Technical Paper Award" 1985 of the Society of Plastics Engineers.

During the coming academic year Professor Nicholas J. Grant will reach his 70th birthday, the normal MIT retirement age. On June 17-18 of this year a group of Professor Grant's former students and colleagues arranged a three day birthday celebration for him at MIT, including a two day technical meeting on "Processing and Properties of Advanced High-Temperature Alloys". We were delighted to have an attendance of 207 individuals - many of them from overseas. A significant fraction of Professor Grant's over 200 graduate students were in attendance, including some of his first students from as early as 1945, and a number of students yet to graduate. Several gifts including a fine oil portrait by Carol Latanision were presented to him at the banquet associated with the meeting. The
most significant gift was a $5000 donation to MIT to initiate the endowed "Nicholas J. Grant Graduate Fellowship". It is the hope of many of those present that over the years this endowment will grow to a point where the income can support a graduate student studying in this Department. We anticipate that Professor Grant will remain active on the faculty as an emeritus professor for many years after his retirement date in July of 1986.

STUDENTS

Undergraduates of this Department who distinguished themselves include Charles T. Lane who received the Department's best thesis award for "Microstructure Analysis of Al Matrix Composites". Melissa Krawiczki and Raymond Meilunas were two of the seven recipients of the James McCormack UROP Award. This demonstrates our Department's deep commitment to undergraduate research and the high standard maintained by the students. Raymond Meilunas also received the Eloranta Summer Fellowship which will enable him to continue his outstanding research over the summer and was one of three recipients of the Kathryn Langford Wolfe Award for combining research in materials and the arts. Undergraduates who received honors from outside organizations include: Laura Bonney who received the American Society of Women Engineers Student Award; Heather Brooks and Mary Manger who were awarded the Digital Equipment Corporation Scholarships; Mary Dionne, the recipient of the New England Mutual Medical Award; and Carl Ulric who received honorable mention, the James F. Lincoln Arc Welding Award.

After a hiatus of some years the undergraduate students have again formed an undergraduate student organization now called the Student Undergraduate Materials Society (SUMS). The Society is governed by an Executive Committee consisting of undergraduate students Mary L. Manger, Louise M. Sedlacek, and Mark A. Wolf. Professor David K. Roylance serves as faculty advisor. SUMS this year organized and ran a successful pizza luncheon seminar series in the Undergraduate Lounge.

Similarly during the spring semester The Graduate Materials Council ran a very well attended seminar series in the Chipman Room in which a faculty member spoke informally on his ongoing research interests; ample time was retained for discussion, interchange, and lunch. The Council is run by an executive committee of graduate students comprised this year of Bruce A. Bishop, Steven A. Gedeon, Timothy V. Johnson, Eric Karten, Jacqueline A. Isaacs, and David H. Matthiesen.

Perhaps the most prestigious and coveted of the graduate student awards at MIT is the Goodwin Medal, given to the single most outstanding teaching assistant for "...conspicuously effective teaching". This year the medal was awarded to Steven C. Semken of this department. The Undergraduate Committee of our department also chooses its own graduate student for best teacher award; this year's recipient was Debra L. Kaiser, who received the John Wulff Award for Excellence in Teaching.

Graduate students who received various honors from organizations outside MIT include: T. David Burleigh who was awarded the H.H. Uhlig Student Award of the Boston Section of the National Association of Corrosion Engineers for 1984; Gerald S. Frankel who received second prize in the Student Research Poster Contest at the National Association of Corrosion Engineers Annual Meeting in 1985; and William D. Needham who received the first prize of the 1985 Graduate Award of the Materials Technology Institute.

Fellowship awards were held during academic 1984-85 by 28 students. These were: AISI, Timothy V. Johnson; ARCO, I-Hen Wang; Beneficial Foundation, Patricia A. Morris; Cabot, Janine M. Nell and Jon M. Peltier; Eastman Kodak, Linda S. Mason; GEM F., Karl W. Reid; Graduate School Endowed, Edmund H. Moore; Hertz Foundation, Alan S. Litsky; Hughes Aircraft, Miriam R. Lachman and Joanna M. McKittrick; IBM Graduate Fellowship, Charles D. Brandt; INCO, Gerald S. Frankel; the Materials Processing Center, Richard H. Benfer, Lawrence A. Cleveneger, and Michael J. Maloney; MMRRI, Robert A. Frank and Debra L. Kaiser, NSF Graduate Fellowships, Nancy F. Levoy, Manuel P. Oliveria II, and James S. Speck; and ONR Research Fellowships, Terry J. Garino and Stanislaus A. Zygmunt; and the Xerox Fellowship in Science and Engineering, Kimberley Elcess.

Partial fellowships held by this Department's graduate students are: a CAES Award held by Michiharu Yamamoto; the Carpenter Technology Fellowship awarded to Jon M. Peltier; The Phillips Laboratories Fellowship (MPC) held by Peter F. Bordui; the TRW Augmented Fellowship awarded to Mollie E. Thompson; and the Wyman-Gordon Grant held by Glenn R. Romanoski.
Our departmental reception following commencement exercises attracted a large number of graduates and their families this year and we suspect we have started an institution.

RESEARCH

Professor Allen continues his important observations of the enhanced coarsening of precipitates at slip bands; he has also joined with Professor Cohen, Dr. Olson and others in a major new research program on "Innovations in High Strength Steel Technology". Professor Balluffi, working closely with Dr. Paul D. Bristow and others continued his broad investigations of the structure and properties of grain boundaries. The Encyclopedia of Materials Science and Engineering, edited by Michael Bever, was published jointly by Pergamon Press and MIT Press. Professor Bowen's multidisciplinary research on controlled processing of ceramic powders continued to receive international interest. Professor Chiang, newly on our faculty, has already initiated studies on microstructure of ternary compounds, ceramic matrix composites, and on novel glass systems.

Professor Clark established the Materials Systems Laboratory in the Materials Processing Center at MIT, with funding from fourteen private sponsors. An objective is to establish a consistent framework for analyzing the demand for materials and the cost of producing and using materials over the medium-to-long term. Professor Morris Cohen continued his active research program on rapid solidification and was a major initiator of the new steel program mentioned earlier. Although Professor Eagar has been on leave during the year, his laboratory continued to make major progress in developing a fundamental understanding of the importance of convection in influencing heat flow and defect formation in welds. Professor Elliott's physico-chemical studies during the last year included work on carbothermic smelting of alumina, interfacial relationships in silicate melts, and formation of sub-micron inorganic particulates. Professor Flemings and Dr. James Cornie expanded significantly their efforts on infiltration and solidification of metal matrix composites. Professor Flemings and Dr. Y. Shiohara developed new techniques for understanding solidification behavior of undercooled melts.

Professor Gatos, working with Dr. Jacek Lagowski and others, obtained a number of important research results including (1) discovery of a new intrinsic gettering process involving native defects rather than oxygen impurities, (2) development of a comprehensive model of heterogeneous dislocation generation in bulk GaAs crystals and (3) development of a new "partially confined" configuration for the growth of semiconductor crystals in space. Professor Grant continued his work on liquid dynamic compaction and developed a linear flat nozzle for producing sheet strip. Professor Hobbs continued his two-fold research thrusts of radiation damage in nuclear materials and high temperature corrosion of metals. He made considerable progress in understanding the crystal to glass transition of ceramics and made a substantial effort on high-dose radiation effects in copper alloys and austenitic stainless steels. Professor Johnson applied his theoretical skills to the study of defects in amorphous silicon solar cells and to metal-semiconductor microelectronic interfaces. He made considerable progress in developing new computer graphics for representing electronic charge distributions in materials.

In Professor Kalonji's computer simulation efforts, she developed new insights into the structure and properties of crystalline interfaces at high temperatures. Among other studies she is also looking at novel processing techniques to create controlled dispersions of particles through devitrification of rapidly solidified ceramics. Professor King has initiated a new program on plasma arc reduction of oxides. Professor Kingery continued his broad research on physical ceramics and completed two edited volumes of research papers. Professor Latanision's research emphasized introduction of modern surface analytical techniques for probing solid electrolyte interfaces. He showed that photoelectrochemical techniques can be used for in situ probing of the electronic properties of thin films on metals in electrolytes. Professor Lechman carried out a series of highly successful experiments in Sussex England in which copper-sulfarsenide ores were smelted in furnaces built after ancient prototypes. Professor McGarry working with Dr. John Mandell and others studied the use of thin elastomeric films in advanced composite materials for high performance air and space vehicles.


Dr. O'Handley continued his aggressive pace of research on the fundamental and technical magnetic properties of amorphous alloys. He collaborated with Professor Johnson on cluster calculation modeling of magnetic materials and worked on application of liquid dynamic compaction to the production of permanent magnets of very high performance; he is also well underway in developing a spin-polarized Auger spectrometer. Professor Owen's work continued unabated on computer calculations of thermodynamic data in multicomponent microalloyed steels and on nitrogen strengthened stable austenitic steels. Professor Pelloux's work on micromechanisms of damage and fracture at elevated temperature provided a number of interesting results, including improvement in fatigue performance by ion nitriding. Professor Ring developed a continuous reactor to produce large quantities of monodisperse ceramic powders; this work has attracted wide attention. Professor Rose clarified the kinetics of formation of superconducting fibers of Nb$_3$Sn in multifilamentary composites and undertook work on a new approach to attachment of total joint prostheses. Professor Roylance continues to work on mechanical properties of polymeric and composite materials.

During Professor Rudman's first year at MIT he established a research program on two interconnected areas of superconducting materials: materials of interest as high current conductors and materials for use in superconducting electronics. Professor Russell undertook a combined theoretical and experimental effort on effects of high intensity neutron and charged particle irradiation on materials, including ceramics. He completed and published an international review on "Phase Stability Under Irradiation". Two significant accomplishments of Professor Sanders's broad research program on molten salt electrolysis are (1) the invention of an aluminum reference electrode in Hall cells, and (2) the measurement of Raman spectra in laboratory-scale cells operating under industrial conditions. Professor R. Erik Spjut, newly appointed to the faculty, is extending and applying to metallurgical systems his thesis research using the electrodynamic thermogravimetric analyzer he developed. Professor Thompson's work continued to focus on solid state kinetic processes in thin film electronic materials. He has shown that in metallic films grain boundary motion can occur at temperatures as low as 20% of the melting temperature, well below the temperature of grain boundary motion in bulk metals (50%). This and other results indicate that observed textures after deposition of thin films are often not the result of oriented nucleation, but the result of surface energy driven grain growth in the early stages of film formation. Professor Tuller delineated the equilibrium phase boundaries for the technologically important quaternary MnZn ferrite system, developed a novel electrochemical technique for studying electronic processes in fast ion conducting glasses, and established for the first time the equilibrium defect and transport properties of yttrium aluminum garnet (YAG).

Professor Vander Sande's research continued to focus on the use of sophisticated electron microscopic techniques to elucidate the microstructure of metallic alloys. During this year, funding for a novel 300 kV, field emission gunned scanning transmission electron microscope (STEM) was secured. Research on phase transformations in Al-Li-Zr alloys received much attention. Professor Wnek made considerable progress in establishing the structure of products from the polymerization of succinonitrile, and identified for the first time cyclic tetramers. He also continued work on ion implantation and specifically on his hypothesis that the carrier sign can be determined by the chemical structure of the polymer to be implanted. Professor Wuensch continued work on synthesis and characterization of fast-ion conducting solids. He developed a novel transport method and used it for successful growth of suitable crystals of high temperature phases of silver and copper chalcogenides; progress was made in designing, from first principles, a new solid electrolyte.
Professor Yannas, having demonstrated for the first time that polymeric templates can induce regeneration of the dermis, is now absorbed in the effort to find out if other tissues (e.g. nerves) can regenerate by use of suitably designed polymeric templates. He has also initiated clinical studies of Stage 2 artificial skin, an advanced design which induces regeneration not only of the dermis but of the epidermis as well. Professor Yurek introduced a new model to explain the mechanisms of oxidation/sulfidation of high temperature alloys. This model is yielding new insights into basic mechanisms. He is also using rapid solidification to develop new oxidation resistant alloys and is developing a model to help delineate ways to promote the formation of reaction products that inhibit corrosion of ceramics.

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 1980's and beyond 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, continued development of the fundamental disciplines, the growing ability to synthesize new materials and processes, and improved understanding of the life sciences and human factors. These rapid changes provide both significant challenges and opportunities to the professional and for the education of future engineers.

Student interest in mechanical engineering has grown substantially in the last decade with an approximate doubling of undergraduate and graduate enrollment from 1975 to the current level of 454 undergraduate and 430 full time graduate students. The Department has the second largest undergraduate enrollment at MIT. 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.

In two recent reviews of the Department educational programs, the undergraduate program leading to an SB in Mechanical Engineering has been recommended for full accreditation by the Accreditation Board for Engineering and Technology and in the recent study by the National Academy of Sciences rating graduate professional programs at US universities, the Department graduate program was ranked as first in the nation.

This past year special emphasis has continued to be placed upon undergraduate curriculum development. Continued upgrading of equipment and instrumentation has occurred in the manufacturing, measurement and instrumentation, project and materials laboratories. A coordinated effort has been initiated to integrate real time data acquisition and analysis techniques into the undergraduate laboratories. Attention has also been focused upon strengthening computational capabilities for both undergraduate and graduate subjects under the auspices of Project Athena.

Faculty effort in identifying and developing research programs in the past year has been notable, particularly in light of the overall support/cost picture. Sponsored research has grown in the last year by five percent to reach a level of $21 million. Approximately one-third of the research is administered directly by the Department and two-thirds by interdepartmental laboratories and centers with which faculty are affiliated. During the last year, small increases in energy, environmental, and transportation research have occurred. Growth has continued in research related to manufacturing and design, while support for biomedical engineering research has remained relatively constant. Research support directly from industry has continued to grow and now constitutes approximately 25 percent of the support 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 established a coordinated laboratory in 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, evaluation 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.
As a result of a generous donation by the Martin Foundation, the Martin Center for Engineering Design has been established. This facility includes a prototype development laboratory, an interactive classroom, and special seminar rooms for design education and research. These facilities will provide a unique opportunity for design education which incorporates computer-aided engineering techniques from concept generation through prototype development.

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 the levels comparable to the past years with a total of 454 undergraduate students. The new sophomore class of 145 included 31 women, 20 percent of the class, and five black students. Approximately 21 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. About 28 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, 58 students from the Department are members of the Program out of a total of 117: 12 graduate students, 19 seniors and 27 juniors. In 1984-85 the Department awarded 157 SB degrees(137 in Mechanical Engineering, 15 without specification, and five in 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 over the next five years 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. Upon the recommendation of the Academic Policy Committee, the faculty adopted a set of regulations defining an overall grade distribution guideline for Department subjects as well as a requirement that a student receive a C grade or better in specified prerequisites to Department core requirements before registering for these core subjects.

In a continuing curriculum development effort this past year, Professors William C. Unkel and C. Forbes Dewey, Jr. have introduced the use of computer-aided data acquisition equipment into two of the Department core undergraduate laboratories. During the next year the acquisition of the computer-based laboratory equipment will be completed. Additional effort has continued in the development of a basic textbook for our core manufacturing subject with Professors Nathan H. Cook and Nam P. Suh providing editorial coordination.
Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: John R. Malloy, Jr., President; Stuart E. Schechter, Vice President; Ruth M. Pricker, Treasurer; and Miriam Maxian, Secretary, continued to make strong contributions to Department and professional activities with a membership of 140 students. Professor Anthony T. Patera 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 continued to grow and approached 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 Gerald J. Baron, President; Neil V. Hamblin, Vice President; Ismael Rodriguez, Secretary; and Howard Richard, Treasurer. Professor Stephen H. Crandall 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: Jeffrey A. Bornstein, President; Faruk Bursal, Vice President; Joe Feehan, Secretary; and Ralf Leszinski, Treasurer with Professor Warren P. Seering acting as Chapter Advisor.

During the year a Student Chapter of the Society of Manufacturing Engineers was established with Professor David E. Hardt as Faculty Advisor. The inaugural chapter officers were: José Rivero, President; Veronica Ng, Vice President; and Toshiki Masaki, Treasurer. The SME held three major activities this past year: two seminars on robotics and a tour of the General Motors assembly plant.

Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

Joshua Makower, a senior, received the Student Service Award for outstanding dedication and service in undergraduate teaching activities.

Several students were recipients of the Departmental De Florez Award for innovation and creativity: Keita Ito won first prize for her design and fabrication of an ultrasonic scanning machine for human joints, Brad L. Braufman won second prize for his robot-mounted tool for wire-handling assembly operations and Steve Meszaros and Andrew G. Ziegler won third prizes for their feedback-controlled rowing ergometer.

Suzanne Dunbar and Laurence Langan won the Departmental AMP award for outstanding performance in project work in the mechanical engineering area.

Kenneth Chen, James Loan, John Pflueger, Jack Phillips, Geoffrey Reynolds, and Luciano Spiridigliozzi won the Departmental Robert L. Hallock Tensile Test Award for excellent machining and heat treating of a tensile test specimen in mechanical engineering.

David R. Cultice, Bradley A. Waller, Ralf Leszinski, Peter Vogeli, William C. Messner, Mark Schlueter, and K. Rahoul Bhandari won the Departmental Wunsch Foundation Silent Hoist and Crane Company award for outstanding design and fabrication in the mechanical engineering area.

Rossana P. Chiang received the William L. Stewart, Jr. Award for her contributions to extracurricular life at MIT.

Michael J. Ambrogi received the Admiral Edward L. Cochrane Award for the highest qualities of humility, leadership, and inspiration in intercollegiate athletics and the Honeywell Award for outstanding academic and extracurricular achievement in engineering and science.
GRADUATE PROGRAMS

Organization

The graduate program is directed by Professor Ain A. Sonin, graduate policy and registration officer, Professor Carl R. Peterson, graduate admissions officer.

Degrees

The Department offers the SM in Mechanical Engineering, the undesignated SM, the degree of Mechanical Engineer, and the doctorate in Mechanical Engineering. The undesignated SM allows students to design special interdisciplinary programs with thesis research performed in the Department, while the Mechanical Engineer program is intended 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 continued to increase and reached 430 full time students in 1984-85. In the fall of 1984 there were 40 women, five black, six Hispanic, and 28 Asian-American students in the graduate program. In September 1984, 296 new students were admitted from 956 applicants and 156 students registered.

In 1984-85 the Department awarded 153 SM degrees (of which 12 were combined SB/SM degrees), four Mechanical Engineer degrees and 21 doctoral degrees.

In 1984-85, 79 percent of all graduate students received support from the Department, MIT funds, fellowships, the government or industry. Fifty-nine percent of the graduate students were supported by the Department through research and teaching assistantships.

Graduate Curriculum Development

During the past year five new graduate subjects were introduced—one in the fluid-thermal science area, 2.272 Physicochemical Hydrodynamics, two addressing experimental methods and techniques 2.68 Theory and Application of Modern Diagnostics and 2.781 Biomedical Instrumentation Electronics, and two related to manufacturing and processing 2.822 Processing of Polymeric Composites and 2.850 Theory and Practice of Machine Tools. Additionally the control systems faculty participated in an interdepartmental effort to develop an engineering schoolwide two term graduate control systems sequence.

RESEARCH

Support Level and Distribution

The total volume of sponsored research for 1984-85 is estimated at $21 million, representing a growth of five percent from the research volume last year. Approximately one-third of the total research is administered through the Department and two-thirds 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 through industry sources. Several laboratory groups derive 50 percent or more of their support from industry including the Resource Extraction Laboratory, the Innovation Center, the Laboratory for Mining and Systems Development, the Laboratory for Manufacturing and Productivity, and the Computer-Aided Design Laboratory.

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 are supported this year by the TRW Foundation Faculty Fellowship, the IBM Grant based on excellence in materials and manufacturing research, the DuPont Engineering Grant and Faculty Fellowship, 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 faction 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. 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 Haruhiko Asada, Neville Hogan, Warren Seering, and Jean-Jacques Slotine. Development of direct drive motors for robots by Professor Asada, 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, and robot control algorithms by Professor Slotine have all been encouraging. Research in polymer processing has been performed through the MIT-Industrial Polymer Processing Program by Professors Suh in materials development, Lewis Erwin in mixing processes, Timothy G. Gutowski in composite materials, and Ming-Kai Tse in nondestructive evaluation. In the area of metals processing, machining and forming, Professor Bruce M. Kramer has continued his research to identify materials for improved tool wear performance in machining of advanced metals including titanium, while David E. Hardt has continued research to improve welding processes and metal forming processes through direct application of automatic control techniques. Dr. George Chryssolouris has initiated a program in laser machining. The industrial consortium under the direction of Professor Ernest Rabinowicz and Dr. Nannaji 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, a new computation facility has been placed in operation by Professors Parks and Anand along with Professors Argon and McClintock. The facility will provide the capability 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 have been applied to the analysis of 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.

A number of faculty are directing their research to development of advanced analytical and experimental techniques in mechanics and dynamics. Professor James H. Williams, Jr. has continued in the development of nondestructive techniques to characterize composite materials. Professor Klaus-Jürgen Bathe has led the development of finite element models for fluid-structural interactions. Professor Crandall has developed analytical formulations and experimental techniques to identify the dynamic behavior of rotor-shaft dynamic systems as well as multi-dimensional plate behavior. Additional research in the mechanics area has been performed by Professor Triantaphyllos R. Akylas who has made significant progress in developing analyses for dynamic wave behavior interacting with coastal shore lines with application to problems of beach erosion.

Energy and Environment

During the year, substantial progress was made in research programs related to the combustion and lubrication in internal combustion engines, resource extraction, heat and mass transfer, and energy 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 newly developed research in the heat and mass transfer area, Professors Patera and Bora B. Mikić 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 consortia to evaluate the uses of ceramic materials in engines and to develop improved understanding of combustion. This effort involves Professors John B. Heywood, Wai K. Cheng and Ahmed P. Ghoniem 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.

In the Chemical Dynamics Research Laboratory, Professors James C. Keck and Unkel have continued the development of a basic understanding of chemical interactions and energy exchange processes associated with electrical discharge phenomena with application to spark ignition laminar burning and homogeneous explosions of combustible gas mixture and arc welding.

Experimental studies to characterize two-phase gas-liquid flows associated with power systems have been conducted by Professors Peter Griffith and Rohsenow with particular application to emergency cooling of nuclear reactors.

Research in the area of turbomachinery has been initiated by Professor Maher A. El-Masri with emphasis on exploration of liquid cooling for gas turbines. 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. In addition, Professor Thomas P. Bligh has recently completed a major project to acquire operating data determining the utilization of solar energy in houses.

A number of fundamental research studies have been conducted this year which are of special significance. 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. Experimental research to determine transport of heat and mass transfer into turbulent free liquid surfaces has been continued by Professor Sonin. Professor Ronald F. Probstein has 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, a new research project has been initiated by Professors Robert A. Mann and Derek Rowell in the areas of computer-aided surgery. Studies conducted in the laboratory by Professor Woodie Flowers have continued the development of a microprocessor-based biofeedback and gait analysis system for training above-knee amputees in the use of prostheses while effort to develop aids for the handicapped has continued by Dr. Michael Rosen. Research results obtained by Professor Ioannis Yannas in collaboration with Dr. John P. Burke of Massachusetts General Hospital to evaluate a Stage 2 biocompatible artificial skin for severely burned patients have been encouraging.

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 Ascher H. 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 Dewey on identifying 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 Laboratory, the Vehicle Dynamics Laboratory, the Machine Dynamics Laboratory, and the Innovation Center.

Professor Thomas B. Sheridan and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of undersea remote manipulation with the establishment of an experimental test capability to evaluate and modify an undersea manipulator in research coordinated with the Woods Hole Oceanographic Institute.

Professor David C. Gossard and his colleagues in the Computer-Aided 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 Professor Steven Dubowsky, James E. Hubbard, Jr., 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. Professor Hubbard has successfully demonstrated experimentally active damping techniques for the control of vibration in distributed structures and is evaluating these techniques for the damping of space structures in a major experimental program.

In transportation technology, under the new program in rail dynamics in which MIT has been designated as an Association of American Railroads Affiliated Laboratory research projects having faculty and staff in Mechanical Engineering and Civil Engineering have been initiated. 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 energy consumption. Research in the control and dynamic performance of automotive vehicles was also initiated by Professor Hedrick.

The Innovation Center, under the leadership of Dr. David Jansson, has continued both basic research into the processes of innovation and development applied to industrial and consumer products. The increased national emphasis on innovation has been reflected in an expanded program in the Center.

FACULTY AND STAFF

Size and Composition

On July 1, 1984 there were 59 active faculty: 32 professors, 17 associate professors (eight with tenure), and 10 assistant professors. Nine faculty are minority group members: a black professor and assistant professor and seven 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: many of these part time faculty serve without stipend. Among the staff are six Asians, one Hispanic, and three women. Of the four administrative staff, two are women and of the 34 support staff one is a black woman. The Department has 14 hourly staff, including two black men.

Notable Accomplishments and Awards

Professor Akylas has been named the 1985 Henry L. Doherty Professor in Ocean Utilization and will attempt to characterize long period edge waves during his two-year term as Doherty Professor. He has also been selected to receive a Presidential Young Investigator Award.
Professor Anand has been appointed the Esther and Harold E. Edgerton Assistant Professor for two years.

Professor Asada, along with Dr. Kamal Youcef-Toumi have been awarded the O. Hugo Schuck Best Paper Award for their paper, "Analysis and Design of a Direct-Drive Arm with a Five-Bar Link Parallel Drive Mechanism."

Professor Cook delivered the 1984 Ralph E. Cross Sr. Lecture in Manufacturing Sciences on "Manufacturing at MIT: An Historical Perspective."

Professor Crandall won the Theodore von Karman Medal of the American Society of Civil Engineers for his "pioneering contributions in random vibration and its applications to structural engineering and structural mechanics."

Professors Erwin and Gutowski have been named cochairman of the MIT-Industry Polymer Processing Program. Professor Erwin has also received an award from NASA along with Mr. John McCree (SM, MIT, 1983), for their innovative work on vented compression molding for the Space Shuttle's External Tank Program. Professor Erwin has also been awarded Fellow of the Society of Plastics Engineers for "outstanding achievement in the field of plastics science or engineering."

Professor Ghoniem received a Certificate of Recognition from NASA for his innovative article published in NASA TECH BRIEFS: Computer Program MIMOC.

Professor Hedrick and his student, Dr. Beaman received a Best Paper Award from the Journal of Dynamic Systems Measurement and Control.

Professor Keck is the IBM Distinguished Scholar of 1985 which was presented by Northeastern University for his lectures and consulting on the chemical kinetics of flames and explosions related to burning rates and "knock" in spark ignition engines.

Professor Patera has been appointed the Rockwell Assistant Professor of Mechanical Engineering.

Professor Rowell received the Graduate Student Council Award for his excellent teaching of and interaction with the graduate students.

Professor Shapiro was the 1984 recipient of the Jacob Pieter Den Hartog Distinguished Educator Award "for excellence in teaching mechanical engineering which has served as an inspiration for students and has fostered the development of physical insight and engineering judgment."

Professor Suh was nominated by President Reagan as the Assistant Director of the National Science Foundation and assumed his duties in October 1984.

Professor Williams has been named a Fellow of the British Institution of Diagnostic Engineers.

New Faculty and Staff

Dr. Jean-Jacques Slotine joined the Department on November 1, 1984 to be affiliated with the Systems and Design Division as an assistant professor.

Resignations/Retirements

Professor Henry M. Paynter has made seminal contributions to engineering education and to systems engineering through development of the bond graph methodology for characterizing physical system dynamics. His continuous enthusiasm and ability to inspire students and colleagues have marked his tenure at MIT.

Professor Warren M. Rohsenow served as the Department graduate officer for more than 25 years. His counsel, advice, and friendship have been highly valued by several generations of students. His research in heat and mass transfer has led to pioneering contributions to the understanding of boiling. He has significantly influenced education and practice in heat transfer through his textbooks and handbooks.
Professor Nathan H. Cook has made substantial contributions to mechanical engineering education through his undergraduate textbook in the mechanics, materials, and manufacturing areas which have been widely accepted and highly valued. His research in manufacturing has significantly increased the knowledge of tool behavior during machining.

Professor Paul M. Houpt resigned in December to accept a position with General Electric in Schenectady, New York.

Professor Lewis Erwin resigned to accept a position at the Kraft Corporation in Chicago.

Deaths

Professor Jerome C. Hunsaker, Professor Emeritus, died on September 10, 1984 at the age of 98. Professor Hunsaker was the aviation pioneer who founded the nation’s first course in aeronautical engineering at MIT. He served as Mechanical Engineering Department Head from 1933 to 1947.

Promotions

Professors Lallit Anand and Bruce M. Kramer were promoted to the rank of Associate Professor.

Mr. Ernesto Blanco was appointed Adjunct Professor.
The Nuclear Engineering Department serves the Institute through four major objectives: 1) by providing education, through teaching and research, to individuals from the U.S. and abroad interested in the peaceful uses of nuclear reactions, 2) by identifying and developing new scientific and engineering approaches to the practical application of nuclear phenomena, and translating these approaches to educational programs, 3) by contributing to a thorough understanding of nuclear energy and radiation in the national and international communities, and 4) by contributing to a thorough understanding of the issues which will determine the role of nuclear power in meeting domestic and world energy needs.

The Department's undergraduate and graduate teaching activities focus around the following disciplines: Fission Reactors, Controlled Fusion, Radiation Science and Technology, and Energy Technology and Resources. Research is carried out by faculty and students as an integral part of our educational program. An important component of the educational strategy is the writing of textbooks and the communication of teaching and research results through professional publications and oral presentations. The demand for public service activities in the Nuclear Engineering Department involving questions of public policy with respect to the commercial application of fission energy and the direction of the fusion research program is strong. This demand is met by testimony on proposed legislation for the Government, short courses and consulting for industry, membership in committees of professional societies, and volunteer work for educational and other non-profit institutions. The following annual report for the period ending June 30, 1985, highlights our recent activities in each of these discipline areas in fulfilling the foregoing Department objectives.

ACADEMIC PROGRAM

During the academic year 1984-85, the Department's graduate program enrolled over 160 domestic and international students. Our undergraduate program consisted of 20 students. Beginning next September, six undergraduates will enter as sophomores to major in the nuclear engineering field.

Our usual policy of recruiting domestic graduate students continued during the past year. Several hundred inquiries were received and processed during this period. At present a total of 45 domestic candidates have applied for September 1985 admission. Financial support has been offered to 34 of the applicants who requested assistance.

The Department awarded 18 doctorates, 2 nuclear engineers, and 28 master of science degrees during the academic year 1984-85--a total of 48 advanced degrees. Also, 10 bachelor of science degrees were awarded.

The Engineering Internship Program continues to be very successful as it enters its eighth year of operation. Seven students—three graduates, three seniors, and one junior—are currently receiving significant on-the-job experience as part of this educational program. Companies which have placed students from our Department include Brookhaven National Laboratory, Commonwealth Edison, EG&G Idaho, Stone & Webster, and Los Alamos National Laboratory.

After meeting regularly for a year and holding a joint seminar for their students, eight faculty members have decided to coordinate their teaching activities under a new program called Radiation Science and Technology (RST). The faculty members are Professors Ronald Ballinger, Gordon Brownell, I-Wei Chen, Sow-Hsin Chen, Otto Harling, Alan Nelson, Kenneth Russell, and Sidney Yip. RST offers a program of studies to students interested in radiological science, condensed matter science, materials science, or radiation health physics. The faculty involved is participating actively in the current curriculum review. Two new subjects were offered by the RST group, a freshman seminar 22.S19 Applications of Radiation in Science, Technology, and Medicine, taught in the fall by all eight members, and a graduate subject involving statistical processes and collision phenomena which was taught in the spring by Professors I-W. Chen and Yip.

Following a decline in national and student interest, subject 22.76J Introduction to Nuclear Chemical Engineering was offered for the last time in the fall term 1984; a considerable part of its content will now be covered in other of the Department's offerings. Similarly, curriculum review led to the condensation of two existing subjects into a new offering, 22.341 Nuclear Energy Economics and Policy Analysis. As part of the same reorganization, subject 22.35 Nuclear Fuel Management will subsequently be offered on an every-other-year basis.
In subject 22.56J, Professors Brownell and Nelson introduced new graduate course material in the rapidly growing area of magnetic resonance imaging in medicine and biology.

A special two-week summer session course entitled, Nuclear Power Reactor Safety was presented once again during the summer of 1984. Under the direction of Professors Norman Rasmussen and Neil Todreas, this offering attracted 75 participants from eight countries.

STUDENT ACTIVITIES

The MIT Student Branch of the American Nuclear Society (ANS) has completed another productive year. Activities have included departmental seminars, student/faculty meetings, departmental steak fries, and course evaluations. The branch also arranged for student participation in the Visiting Committee meeting held last October.

Honors and Awards

Two of our graduate students were honored by the ANS at its annual meeting held in Boston earlier this month. David Petti was the recipient of the Robert A. Dannels Memorial Scholarship, and the Verne R. Dapp Memorial Scholarship was presented to Robert Witt. Students compete nationally for these awards which are given to recognize an individual's outstanding academic excellence.

At the eastern regional student conference of the ANS, "best presentation" awards were presented to two of our graduates: Joy Maneke in the area of criticality and safety and Bob Witt in the area of fusion energy.

Last April, Alpha Nu Sigma, the national honor society for nuclear science and engineering, held its annual induction ceremony. At this dinner meeting six graduates and two undergraduates were welcomed as new members.

Recipients of our undergraduate awards were announced last April. The Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering was presented to Jerry Martin. Jay Elson was selected to receive The Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

Several of our graduate students were honored with national fellowships during the past academic year. Department of Energy (DOE) Magnetic Fusion Energy Fellowships were awarded to James Doyle, Deborah Hanchar, Scott Haney, John Massidda, and Craig Petty. Other continuing DOE-sponsored fellowship holders included Anthony D'Amico, Margarita Crocker, Gary Moland, and Tue Nguyen. Madeline Woodruff and Michael Izenson were fellowship recipients from the National Science Foundation (NSF).

For the third year, Jon Anderson was named a Schlumberger Fellow in Radiation Physics. The Schlumberger Foundation also provided partial support for Susan Cooper. Cynthia Nitta continued to receive an IBM Fellowship for her graduate research in materials science. Also during 1984-85, the General Electric Foundation awarded Gordon Shed a fellowship. Dean Miller was appointed by the Institute as a Rockwell International Graduate Fellow for the past year.

The Department selected Kirby Burkholder and Chris Wilson for fellowships supported by the Institute of Nuclear Power Operations. Daisy Chien, David Kennedy, Robert McKinstry, Bruce Parnas, and Suzanne Shedd received partial support from funds provided by the National Institutes of Health for their study in the area of radiological science.

Other Student Awards

During the academic year, approximately 65 percent of our graduate student body was appointed to the graduate student staff, receiving financial aid in the form of full- and part-time research and teaching assistantships.

The Theo J. Thompson Memorial Fellowship was awarded to Tsang-Lang Lin. The Sherman Knapp Scholarship, funded by Northeast Utilities, was presented to Ken Rempe. Our newest fellowship, in honor of our first department head, Professor Manson Benedict, was held by Cynthia Elliott.

Rene Sanchez and Robert Scott received financial assistance from the Graduate and Professional Opportunities Program. A NASA fellowship was awarded to Warren Kreuger to continue his research during the year. The Department's two MIT-endowed tuition scholarships provided funding for approximately nine graduates.
RESEARCH

The Department conducts research in the areas of 1) fission reactors (reactor engineering, reactor physics and fuel management, nuclear materials, and reliability and risk analysis), 2) controlled fusion (applied plasma physics and fusion reactor technology), 3) radiation science and technology (condensed matter sciences, biomedical and radiological science), and 4) energy technology and resources. During the fiscal year ending June 30, 1984, Departmental faculty supervised a research volume of $3,329,722, including research funded through the Department, the Department of Materials Science & Engineering, the MIT Energy Laboratory, the Whitaker College of Health Sciences, Technology and Management, the Nuclear Reactor Laboratory, the Plasma Fusion Center, and the Research Laboratory of Electronics.

Continuing Research Projects

Following their work on the Department's Nuclear Power Plant Innovation Project, Professors David Lanning, Lawrence Lidsky, and Michael Driscoll have initiated a major program aimed at contributing to the development of Modular High Temperature Gas-Cooled Reactors (MHTGR) as a complementary nuclear power source for the near term. This project, and the associated MHTGR study group, has grown rapidly. Besides several faculty, there are now seven students involved in thesis research. Funding for this research is being provided by the Energy Laboratory Utility-Sponsored Program, GA Technologies, and the Nuclear Regulatory Commission (NRC).

Also as part of the Nuclear Power Plant Innovation Project, a study of alternative federal policy options for advanced reactor development and commercialization was completed under the direction of Professor Richard Lester. This project was supported by the NSF. Professors Driscoll, Michael Golay, Lanning, and Lidsky also participated in this work.

Professors Lanning, John Meyer, and Andrei Schor, working closely with the Charles Stark Draper Laboratory staff, are continuing their research on instrumentation, control, and information processing for nuclear power plants. Argonne National Laboratory is providing partial funding for studies related to the development of the EBR-II instrumentation demonstration. An important part of this program has been the use of the MIT Research Reactor (MITR-II) for demonstration and also research in fault-tolerant digital control systems. Funding for the MITR-II related research has been received from the NSF and the Charles Stark Draper Laboratory with Professor Lanning and Dr. John Bernard of the Nuclear Reactor Laboratory as principal investigators. This research involves transfer of aero-space technology to the instrumentation and control of nuclear power plants. Professor Rasmussen is continuing his research on prediction of the amount of radioactive release for postulated nuclear power plant accidents. This work is being supported by the Idaho National Engineering Laboratory. Under the sponsorship of the Electric Power Research Institute (EPRI), Professor Mojid Kazimi is continuing research in the area of PWR severe accident analysis and also participating in the review of the German large scale experiments on corium-concrete interaction.

In the reactor physics area, Professor Allan Henry and his students have continued work in the area of reactor physics modelling. Some of the numerical methods developed in this effort have been embodied by EPRI and by Nuclear Utilities Services into production computer programs for thermal reactors and are now being tested by utilities. During the past year, Professor Driscoll's students continued research on improved Light Water Reactor (LWR) fuel management methods.

In the area of nuclear materials, departmental research continues to be active. Development of improved nuclear structural alloys for the critical fusion reactor first-wall application is being explored by Professor Harling. A major theoretical and experimental effort focusing on the effects of high intensity neutron and charged particle irradiation on the microstructures and properties of metals and ceramics of interest in fusion and advanced fission reactor systems is being investigated by Professor Russell.

Professor Ballinger has several research projects ongoing, one of which explores the environmental effects on fatigue and stress corrosion cracking performance of materials used for nuclear power systems. In another project, an effort is under way to model the chemistry, electrochemistry, and hydrodynamics of a crevice or stress corrosion crack in high temperature aqueous systems. Still another project seeks to develop an understanding of the relationship between structure, properties, and thermomechanical processing in nickel-based alloys in nuclear systems. The experimental laboratory for his research has been expanded with the addition of a new servohydraulic fatigue machine and associated equipment for the study of mechanical properties at 4.2°K for fusion reactor applications.

Professor Ballinger is also continuing his efforts in the area of predicting LWR fuel performance using advanced deterministic and probabilistic techniques and is adapting the same methodology for use in
materials-related areas including alloy development and component life prediction. He has also been active in research related to Three Mile Island. An examination was conducted at MIT to determine the morphology, chemistry, and phase distribution of fuel debris in samples extracted from the reactor. This was the first attempt to do microchemical analysis of fuel debris. The program is ongoing and promises to lead to a better understanding of the actual sequence of events during the accident.

The Department continues its broad activities in the area of thermal hydraulics and fluid flow. Professors Kazimi, Lanning, Schor, Todreas, Golay, and Meyer have contributed individually and jointly to studies of natural convection and sodium boiling behavior in Liquid Metal Fast Breeder Reactor (LMFBR), PWR steam generator modeling, LWR containment flows, single- and two-phase flow in light water reactors, and thermal problems in fusion devices. In the computational thermal-hydraulics area, Professor Schor continues his research on advanced numerical methods, aimed at providing efficient, multi-dimensional analytical tools. Investigations of the especially severe nonlinear effects characterizing the two-phase flows are being actively pursued. Professor Golay leads a project examining the opportunities and problems of LWR plant life extension.

In the fusion area, research has continued over a wide range of topics. Professor Jeffrey Freidberg's studies of the macroscopic equilibrium and stability properties of plasmas using the magnetohydrodynamic model are continuing. Specific problems are being investigated relating to stellarator, stellarator/tokamak hybrids, and tandem mirrors. Plasma turbulence and the resulting anomalous transport, particularly in tokamaks is being further studied by Professor Kim Molvig. This work focusses on drift wave turbulence and the calculation of saturated states and frequency and wavenumber spectra. Research on nonlinear ordered and stochastic systems with various applications to laboratory and astrophysical plasma turbulence has been continued by Professor Thomas Dupree. Professor Ian Hutchinson is continuing his interest in the areas of plasma diagnostics and MHD instabilities and is conducting experiments on the Tokamak Alcator C.

Professor Elias Gyftopoulos is continuing his work on the foundations of quantum thermodynamics.

Professor Meyer has continued engineering analysis work applied to first walls, blankets, and steam turbines in tokamak fusion system studies. Professor Kazimi has continued his studies of fusion reactor safety, with major emphasis on the development of a methodology for assessment of reactor design impact on safety. He has also initiated experimental studies of lithium fire kinetics.

Professors S-H. Chen and Yip lead the Department's efforts in the area of applied radiation physics. Professor Chen's major research area is in thermal neutron scattering spectroscopy of liquids and small angle neutron scattering studies of micelles and micro-emulsions. Professor Yip is now primarily interested in computer simulation studies of materials behavior and properties. In the area of nuclear medicine, Professor Brownell's study of boron neutron capture therapy with emphasis on the development of track etch technique for determining boron distribution in tissue is continuing. His medical imaging program which focusses on positron tomography and the development of instruments and radiopharmaceuticals as well as biological and medical applications continues in conjunction with the Massachusetts General Hospital. An NMR imaging device will be installed in the Magnet Laboratory.

In the area of radiological science and radiation biophysics, Professor Nelson has several research efforts ongoing. In collaboration with the Lawrence Berkeley Laboratory, he is investigating the effects of ionizing photons and particles on cancer and tumors. In conjunction with the Harvard Medical School, study continues on the effects of ionizing radiation on vasculature. This project is directed toward improved methods of tumor treatment. Professor Nelson is also continuing various investigations in microstructure of organisms and materials, and in laboratory automation and digital image analysis.

Study in the area of radioactive waste management and disposal has continued under Professor Lester's supervision. During his research, there has been 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 Lester is continuing his research into the sources of international variations in industrial performance in nuclear power plant construction and operation. This work is supported by the Andrew W. Mellon Foundation.

New Research Projects

Professor Driscoll has obtained funding for research on passive shutdown energy removal and on licensing strategies for the new liquid metal cooled fast reactor (LMR) designs now under review by the DOE and
its contractors. Together with Professor Lanning, he is also working on a new project to evaluate problems associated with the control of multi-module LMR and MHTGR units.

A project investigating steam generator tube rupture events has been initiated by Professor Schor, in conjunction with Los Alamos National Laboratory. He is also directing an effort aimed at providing advanced simulation tools for educational and research uses. This work will be partially supported by a grant from the ATHENA project.

Professors Lanning, Meyer, and Schor are jointly involved in a new project entitled, Plant Performance Monitoring. The work is being supported jointly by Northeast Utilities and the Foxboro Company. Professors Lanning and Rasmussen are involved in a research effort to estimate the risks from accidents in MHTGRs.

Professors Rasmussen and Ballinger have initiated a project to develop methodology to predict high level radioactive waste disposal container life. The DOE Office of Nuclear Waste Isolation is providing support for this work.

Professor Ballinger has also initiated a project with the David Taylor Naval Ship Research and Development Center to investigate structure/property relationships in steels used for pressure vessels and structural applications. In an effort with Professor Eric Beckjord, a proposal has been submitted to the DOE to employ advanced pattern recognition techniques in the evaluation of component failures in nuclear power plants.

Under the supervision of Professors Beckjord and Golay, projects have been initiated in the areas of development of a non-prescriptive nuclear safety regulatory methodology, of implementing the "leak-before-break" concept in nuclear plant design, and of refining the simplification of nuclear plant designs. This work has been funded partially by the NRC and by Stone and Webster Engineering Corporation.

During the past year, several projects have been initiated by Professor Kent Hansen. One project deals with developing electronic simulation of nuclear plant dynamics using the MIT-developed "parity simulator" technology. Other faculty involved include Professors Golay, Henry, and Schor. Under Professor Hansen's supervision, research is being conducted in the area of thermal plasmas, fracture mechanics, automated welding, and engineering analysis and design. Twelve faculty from five departments are involved in this effort which is a DOE-sponsored program on energy engineering.

In collaboration with Dietmar Winje of the Technical University of Berlin, Professor Hansen has initiated work to acquire and analyze data regarding the comparative performance of light water reactors in the U.S. and West Germany. Next year we expect to expand this research to consider more nations and in so doing involve Professors Golay, Gyftopoulos, Lester, Rasmussen and Schor. Sponsorship initially came from EPRI and the Center for Energy Policy Research.

**FACULTY**

Eric Beckjord joined the department as a visiting professor of nuclear engineering.

Professor Hansen was named Associate Director of the Energy Laboratory. His responsibilities include the Electric Utility Program, the Northeast Residential Experiment Station, Nuclear Energy, and Energy Engineering.

Professor Lester was selected as the second holder of the Atlantic Richfield Career Development Professorship in Energy Studies at MIT. This is a two-year appointment.

Professor Meyer was on sabbatical leave during the spring term 1985. During this period he gathered material to improve the notes in his fall term structural mechanics subject. He also participated in specifying advanced techniques to be incorporated in computer programs in two plants of Northeast Utilities.

Professor Rose retired from the department as a full-time faculty member at the end of the fall term. After spending the spring term in Honolulu, he will return to the department next fall to teach the energy assessment course.

Department administrative responsibilities were handled by several faculty members during the past year. Graduate admissions were reviewed by Professor Lanning, and Professor Yip continued as financial aid officer. Professor Driscoll served as graduate recruiting officer. Professor Henry represented the Department to the Committee on Graduate School Policy (CGSP). The Committee on Undergraduate Students
chaired by Professor Meyer and by Professor Ballinger during Professor Meyer's absence. Professor Meyer served as the faculty advisor for both the honorary Alpha Nu Sigma Society and the ANS Student Branch. UROP activities were coordinated by Professor Ballinger. He was also in charge of our Engineering Internship Program. Our department's IAP activities were directed by Professor Schor.

Department faculty have actively participated in both Institute and national professional activities throughout the year. Professor Rasmussen continues to serve as Chairman of the MIT Committee on Reactor Safeguard, as well as Chairman of the MIT School of Engineering Committee on Energy Systems. He continues to chair both the Scientific Review Committee and the Fusion Safety Committee at the EG&G Idaho National Engineering Laboratory. He holds an appointment to the National Science Board and also serves on the Scientific Advisory Board for the Cleanup of TMI-2. He was a member of the Ad Hoc Committee on Technology, Policy and Society Studies at MIT.

Professor Gyftopoulos continued his services as Faculty Chairman of the MIT Sustaining Fellows Program, and as Chairman of the Committee on Discipline. He was also appointed a member of the Committee on Energy Conservation Research of the National Academy of Sciences and the National Academy of Engineering. He also serves on the Working Group appointed by the Deans of the Schools of Engineering and Humanities to study the history of the humanities requirements for engineering students at MIT and other institutions.

Other faculty selected to hold Institute appointments include Professors Henry, Driscoll, Lester, and Russell. Professor Henry is a member of the MIT Advisory Committee on Shareholder Responsibility. He is also the CGSP representative to the Committee on Educational Policy (CEP). Professor Driscoll continues to serve on the Institute Committee on the Writing Requirement. Professor Lester was appointed to the MIT Committee on International Institutional Commitments. The School of Engineering Committee on Minorities and Women is chaired by Professor Russell.

Professor Harling continues to direct the interdepartmental Nuclear Reactor Laboratory. Faculty members serving on the MIT Committee on Reactor Safeguard include Professors Lanning, Kazimi, and Ballinger.

Professor Lanning holds membership 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 and Webster Engineering Corporation. The Nuclear Heat Transfer Committee of the American Institute of Chemical Engineering is chaired by Professor Kazimi. He is also the chairman of the Advisory Committee of the DOE Fellowship for Magnetic Fusion Energy Technology.

Professor Driscoll is a member of the Executive Committee of the Fuel Cycle and Waste Management Division of the ANS. Professor Todreas also serves on the Executive Committee of the ANS. He also chairs the EG&G TMI-2 Accident Analysis Industry Review Group.

Professor Lester serves as chairman of the Systems Review Committee of the Office of Crystalline Repository Development at Battelle Memorial Institute. Professor Meyer is a member of the Review Committee for the Applied Physics Division at Argonne National Laboratory.

Two faculty members are represented on editorial review boards: Professor Todreas on the thermal design section of the Journal of Nuclear Engineering and Design; Professor Henry on the Nuclear Science and Engineering Review Board.

Faculty participation in various workshops/seminars continued over the year. Professor Lester directed a major conference on national advanced reactor research and development strategies. This conference was held in January in Cambridge and involved US and international participants from government, industry, and research organizations. Last September, Professor Kazimi was invited by the University of Stuttgart to be a guest lecturer.

Professor Lidsky's call for a review of the goals of the national fusion program continued to attract wide attention both in the US and abroad. During this period, he was deeply involved in the still-continuing discussions, presenting invited papers at, among other places, Princeton, Argonne National Laboratory, and the Washington meeting of the American Physical Society.

Professor S-H. Chen was appointed the Vice-Chairman of the Gordon Conference on Water and Aqueous Solutions which was held in New Hampton, New Hampshire last August. In February he, along with colleagues from UCLA and Cornell, organized an NSF workshop of the Physics and Chemistry of Surfactants in Solutions. He was invited by the American Chemical Society to organize a symposium on Statistical Thermodynamics of Micellar and Microemulsion Systems for its national meeting which was held in Miami Beach.
Professor Golay led the Energy Laboratory's Electric Utility Program workshop. This workshop focused upon materials problems of nuclear power stations reflecting the increasing importance of such problems as the current generation of plants grows older.

A special seminar for high school science teachers was organized and conducted by Professor Driscoll at the annual meeting of the ANS which was held recently in Boston. At this meeting Professor Schor was responsible for chairing a special session. He also served as session chairman at the Eleventh Liquid Metal Boiling Working Group in Grenoble, France.

**Honors and Awards**

During the past year, Professor Henry received the honor of election to the National Academy of Engineering. Last May Professor S-H. Chen was named a fellow of the American Association for the Advancement of Science. Professor Nelson received an endowed chair entitled, the W.M. Keck Foundation Associate Professor of Biomedical Engineering. The Student Branch of the ANS presented its annual outstanding teacher award to Professor Ballinger.

**SUMMATION**

Among the many departmental activities which took place during this year, of special note was the Nuclear Engineering Department Alumni reception hosted together with the MIT Alumni Association in June 1985. This activity brought back to MIT many departmental alumni who were in Boston to attend the annual meeting of the American Nuclear Society. The reception followed an afternoon of briefings by the department head and departmental faculty.

Also of special interest was the May 1985 departmental presentation to the Advanced Concepts Subcommittee of the EPRI Nuclear Power Division Advisory Committee. This briefing was held in response to a request by this EPRI committee, which was interested in keeping abreast of advanced reactor activities carried out nationwide. Agenda items were nuclear engineering education at MIT and nationwide, national reactor development priorities, LWR advanced design activities, LWR dose reduction, and HTGR advanced design activities.

Also of import and relative to the needs of our student population, the Department is happy to report that during this fiscal year computer facilities in three locations in which our students are housed were equipped with new computers and/or existing equipment was upgraded.

And finally, the Department has held considerable discussion regarding review of its curriculum and the associated structure of the doctoral qualifying examination. A major focus has been the role of experimental experience in the graduate curriculum and the means to insure our students receive such experience. By the fall of 1985, the revised list of courses and qualifying examination requirements will be adopted.
PROGRAMS OF INSTRUCTION

Undergraduate Program

The undergraduate curriculum has undergone major changes that are intended to give substance to our decision to emphasize the teaching of design. A new sophomore-level subject, 13.00 Computer-Aided Hydrostatics and Hull Surface Definition, was introduced in the fall term (details below under Project Athena), and our follow-on subject, 13.40 Elements of Ocean Engineering Design, was modified in the spring term for the same purpose, with more changes to come next year. As we increase the stress on design, we also introduce more uses of the computer, both as an introduction to computer-aided design and as an aid in teaching.

The major undergraduate subjects in the Department, 13.901 Ocean Engineering Laboratory I and 13.902 Ocean Engineering Laboratory II, have also been completely reorganized by Professor A. Douglas Carmichael to provide support to the teaching program in design.

Graduate Programs

A School-wide committee recently reorganized and codified graduate subjects in the general area of controls and control systems. A decision was made to offer two broadly-based subjects, which could then be followed by specialized subjects in the various departments concerned. Associate Professor Michael S. Triantafyllou was a member of the committee, and he will be co-in-charge of one of the basic School-wide subjects. He will also offer an advanced subject on the control of ocean-engineering systems.

Assistant Professor Paul D. Sclavounos offered for the first time a new graduate-level subject 13.03 Wave Forces on Marine Structures.

In 1984 a new subject, 13.64 Projects in Ocean System Management, was offered as the capstone of the SM program in Course XIII-B. In this subject, the entire class works as a team on a single project. This year the subject was offered again, the topic being strategic and tactical planning for the control of oil spills. In this subject, students gain some understanding of the real-life problems of managing an engineering system that has multiple nontechnical aspects, including legal, policy, and financial ramifications.

PROJECT ATHENA

Project Athena became a reality this year in that several changes in curriculum and teaching methods that were developed under its sponsorship went on line in under-graduate programs throughout MIT. The Department of Ocean Engineering participated in these developments and provided leadership in some. Two have been particularly noteworthy:

(1) Professor Justin E. Kerwin offered a new sophomore-level subject, 13.00 Computer-Aided Hydrostatics and Hull Surface Definition, in the fall. To a large extent, the subject matter is traditional naval architecture. What is new is the method of presentation, which provides a new learning environment for students. After being introduced to the basic principles, students have the opportunity to develop an intuitive understanding of their significance by applying them repeatedly in simple, efficient ways on the computer. The teaching programs make extensive use of interactive computer graphics, so that visual images reinforce the learning experience. Students have many opportunities to ask "what if" questions and to follow through on the consequences. This project is now being extended to the follow-on design subject, 13.40 Elements of Ocean Engineering Design, which is taught by Professor Chryssostomos Chryssostomidis.

(2) Professor Jerome H. Milgram directed an Institute-wide project to develop a user-friendly interface between student laboratories and Project Athena. The purpose was two-fold: (a) Students at MIT are exposed to a variety of laboratory experiences, in each of which they must first learn how to use not only the measuring equipment but also whatever data-acquisition and data-processing equipment happens to be available in the laboratory. The new system was
intended to introduce a high degree of uniformity into the latter, so that students could spend more time learning from the experiments and less time just becoming familiar with special-purpose equipment. (b) Modern data processing requires that many computer-based capabilities be readily available (digital filtering, statistical analysis, Fourier analysis, etc.). Such capabilities have not been available in many student laboratories, and those that existed varied greatly in quality and ease of use. Their diversity was a major obstacle to their effective use by students. Such capabilities could be provided through Project Athena if uniform laboratory interfaces were available. This was the second goal, and it presented a greater challenge. For example, it meant that hardware in the data-acquisition systems (the real-time clock, status registers, control registers, etc.) had to be accessible through the high-level languages (Fortran and C) supported by Project Athena. This is not an ordinary requirement on laboratory equipment, and so it had to be developed. Professor Milgram and his coworkers accomplished this in just a few months, and they were able to install eight machines in laboratories in three departments at the beginning of the fall term. These numbers were doubled for the spring term.

RESEARCH

Arctic Research

Government and industry interest in the Arctic region continues to grow, and the Department of Ocean Engineering devotes major resources to this subject. Our Arctic-related activities can be divided generally into studies in two areas, (i) ocean acoustics in the Arctic and (ii) properties of sea ice and ice/structure interactions.

The MIZEX 84 (Marginal Ice Zone Experiment of 1984) field program was one of the largest programs ever conducted in the Arctic, involving seven ships, twelve aircraft, and over 200 scientific personnel. Professor Ira Dyer heads the planning and coordination efforts in the MIZEX acoustics program, one of seven disciplines in the program, and Professor Arthur B. Baggeroer also carries major organizational responsibility.

Professor Dyer has been focusing his research on two topics, (a) measurement of ambient noise and the analysis of its origins and (b) backscattering from major submerged topographic features and the ice canopy. Professor Dyer and his students have shown that ambient noise can be caused by ice motions that result from several distinct environmental loads (wind and current in pack ice and marginal ice, temperature variations in pack ice and marginal ice, gravity waves in marginal ice, and floe collisions in loosened pack ice and marginal ice). Radiated noises resulting from these various loads appear in distinct portions of the spectral domain, because they affect disparate structural length scales; this separation helps greatly in their measurement and analysis. In studying backscattering, the Ocean Engineering group has pioneered in the development of measurement and analysis techniques that have now been used to demonstrate the existence of a "pathological" topographic backscatterer in the eastern Arctic. In earlier work, they had already shown the existence of a previously unknown topographic backscatterer in the Beaufort Sea. These backscattering regions do not yet have accepted geological interpretations.

Professor Baggeroer's specific research interests are in long-range, low-frequency, seismic/acoustic propagation, array processing, and acoustic telemetry. In the marginal ice zone, the tethered hydrophone arrays that had been used in the pack ice had to be replaced by untethered telemetry systems, which were placed on ice floes and allowed to drift. Coherent array processing of acoustic and seismic data requires that sensor locations be known within a quarter of an acoustic wavelength. Such precision was generally found to be attainable in tests at short range. Problems resulted primarily from telemetering difficulties and the destruction of instruments by polar bears.

Major contributions to these projects are also being made by Associate Professor Peter N. Mikhailovsky of this Department and by Assistant Professor Gregory L. Duckworth of the Department of Earth, Atmospheric, and Planetary Sciences, who was until this year a research engineer in this Department.

The interactions between ice and man-made structures are a major concern to the oil and gas industry as it explores more and more widely for hydrocarbons under the Arctic continental shelf. We had been moderately active in this area for several years, but we were able to intensify our efforts starting two years ago when we were awarded (jointly with the Department of Civil Engineering) a major grant from the Sohio Foundation for the establishment of a Center of Excellence in Offshore Engineering. Professor Tomasz Wierzbicki and Assistant Professor Dale G. Karr have published or presented six papers this year alone on the mechanics of ice. In
November, Professor Wierzbicki and Associate Professor Xirouchakis (who resigned in January) organized an international workshop on the breaking process of ice plates, and Professor Wierzbicki organized another related workshop in May. In a short time, we have achieved a position of leadership in this important field.

Propeller Design

The current search for improved methods of designing marine propellers is driven by several conditions, (a) the universal need for improved efficiency (and lower fuel costs), (b) severe increases in vibration levels in some ships built in recent years, caused by adverse propeller/hull interactions, and (c) the need, especially in the Navy, to operate ships more quietly. In the last two decades, progress in solving such problems has accelerated greatly, largely because of the availability of large computers. More recently, experimental techniques have improved rapidly, most notably because of the availability of laser velocimeters: For the first time, we can actually measure the velocity of the fluid without disturbing the flow. MIT is recognized as a world leader in propeller research, and, since the resignation of Associate Professor Robert J. Van Houten one year ago, this reputation depends on the accomplishments of just one member of our faculty, Professor Justin E. Kerwin. Professor Kerwin is pursuing several projects, each of which addresses an important fundamental problem of modern propeller design. Several of these have produced noteworthy results recently:

(i) Current propeller design methodology ignores the presence of the propeller hub. A result, as shown by Professor Kerwin and one of his students, is that the propeller root (the part near the hub) generally operates very inefficiently; worse yet, hub cavitation may be increased. His recent research suggests ways to improve hub and root flow, but it also raises many new questions. (Among these questions: Can a properly-designed propeller/hub combination actually be manufactured?)

(ii) Several years ago, Professor Kerwin and a doctoral student developed and validated a computer code for predicting nonlinear effects in hydrofoil/cavity flows. The code was very complex and was practical only for two-dimensional problems. This year, another doctoral student developed a linear analysis and code that predicts the essential features of the nonlinear phenomena, and the new method can feasibly be extended to three dimensions.

(iii) The design of propeller/hub systems and other fin/body combinations depends on the validity of certain assumptions that are universally accepted in ideal-fluid theory, in particular, the assumption that circulation is continuous. Most people working in fluid mechanics believe that "it has to be true." In fact, we can find no indication that it has ever been verified experimentally. Since it is an assumption relating to an ideal fluid, and there is no such thing as an ideal fluid, an experimental verification should have been made long ago to determine that the assumption is valid for a real fluid. Special apparatus was designed, built, and tested for this purpose. We can now state authoritatively that the assumption is valid for a real fluid (such as the water in the variable-pressure tunnel). This result is hardly unexpected, but it is important, well worth the demanding experiment that was required to get it.

PATENTS

"Oil Collector for Subsea Well Blowouts for Installation on a Seabed," US Patent #4,456,071 (J. H. Milgram)

FACULTY

Professor A. Douglas Carmichael has been serving as Vice Chairman of the New England Section of the Society of Naval Architects and Marine Engineers and will be Chairman next year.

Professor Ira Dyer has been chosen to be President of the Acoustical Society of America.

Professor Ernst G. Frankel returned from a one-year leave, when he was serving the World Bank as Advisor on Ports, Shipping, and Aviation. He continues to be active as a consultant to the World Bank.
Captain Clark Graham, USN, joined the faculty this year as Professor of Naval Construction and Engineering. He is head of Course XIII-A.

Associate Professor Judith T. Kildow was appointed to the National Advisory Committee on Oceans and Atmosphere. She continues to serve on the Ocean Science and Policy Board of the National Academy of Sciences/National Research Council.

Associate Professor Henry S. Marcus was on leave this spring to work on several research and publication projects.

Professor Koichi Masubuchi was Chairman of the US Organizing Committee for the 1984 Annual Assembly of the International Institute of Welding.

Professor Peter N. Mikhalevsky received the A. B. Wood Medal and Prize from the Institute of Acoustics (UK) and presented the Wood Medal Address in Birmingham. Professor Mikhalevsky has resigned from the faculty, to be effective later this summer.

Associate Professor Harilaos N. Psaraftis has been awarded permanent academic tenure.

Assistant Professor Paul D. Sclavounos has been promoted to Associate Professor.

Associate Professor J. Kim Vandiver has been promoted to Professor. He will be Associate Chairman of the Institute faculty in the coming year, and he continues to serve as Director of the Experimental Study Group in the School of Science.

Commander W. David Whiddon, USN, joined the faculty this year as Associate Professor of Naval Construction and Engineering. He is the Academic Officer of the military students in Course XIII-A.

Associate Professor Paul C. Xirouchakis resigned from the faculty in January to accept a tenured faculty position at the National Technical University in Athens, Greece.

Assistant Professor Dick K. Yue has been named Chairman of the Department's Undergraduate Program Committee.

CONFERENCES SPONSORED

The Ocean Engineering Department and the Sea Grant Marine Industry Collegium jointly sponsored a colloquium on The Role of Computers in Engineering Design, October 30, 1984. The discussions were focused on the issues involved in the use of computers in engineering-design areas, with emphasis on the shipbuilding, aerospace, automobile, and offshore industries. The speakers at this colloquium were Mr. Laird E. Johnston, General Motors, Inc., Mr. Williard R. Bischoff, Grumman Corporation, Captain John F. Leshy III, U.S. Navy Program Manager, Mr. Dan Whitney, Draper Laboratory, Mr. Harry E. Stephanou, Exxon Production Research Company and Mr. John E. Agapakis, MIT.

Professor Tomasz Wierzbicki and Professor Paul Xirouchakis organized a workshop November 1-2, 1984 on Breaking Process of Ice Plates. This workshop was sponsored by the Center for Scientific Excellence in Offshore Engineering and the MIT Sea Grant Program. The primary objective of this meeting was to discuss important issues concerning the determination of forces needed to break ice plates under transverse and in-plane loading and the understanding of ice failure at various size levels. Twenty-two participants from academic and government institutions, consulting firms, and the oil industry presented papers and participated in the many open discussions that were held during this two-day meeting.

Education for Innovation in Ship Design — A Tribute to Henri Kummerman, 1908-84, was sponsored by the Ocean Engineering Department May 13, 1985. Henri Kummerman was an advocate of innovation in the shipping world. He founded The Henri Kummerman Foundation to implement his "profound desire... to encourage innovation and ability in the maritime field." It was decided that a fitting tribute to this pioneer of the marine industry would be to sponsor a one day seminar focusing on innovation of ship design with presentations from three teams of students, undergraduate, graduate, and Navy. Each team demonstrated new computer techniques being used in constructing ships and offshore structures.
A second workshop on ice mechanics was held at MIT on May 29, 1985. This meeting was organized by Professor Tomasz Wierzbicki for the purpose of discussing the problem of ductile-to-brittle transition and softening in ice. The participants, who were again a well-rounded representation of the ocean engineering field, reviewed the most recent published and unpublished papers pertinent to this problem. The Center of Scientific Excellence in Offshore Engineering at MIT assisted in funding this workshop.

ROBERT BRUCE WALLACE ACADEMIC PRIZE AND LECTURE

The fifth Robert Bruce Wallace Prize, for the 1985-86 academic year, will be awarded to Mr. Peter A. Quigley. This prize was endowed by Albert H. and Marion W. Chatfield in memory of Mrs. Chatfield's father, Robert Bruce Wallace, Class of 1898. The fourth Robert Bruce Wallace Lecture was presented by Dr. Bertram Herzog on October 29, 1984; his subject was "New Directions for Computer-Aided Design".

T. FRANCIS OGILVIE
Artificial Intelligence Laboratory

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, intelligent supercomputing, and music cognition.

Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky works on general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Dr. J. Michael Brady, Professor W. Eric L. Grimson, Professor Berthold K. P. Horn, Professor Tomaso Poggio, and Professor Shimon Ullman do research in computer vision. Professor Rodney A. Brooks, Professor John M. Hollerbach, Professor Tomás Lozano-Pérez, 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 Thomas F. Knight 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, in collaboration with Professor Harold Abelson of the Laboratory for Computer Science, is preparing 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 166 members include 15 faculty members, 10 academic staff, 56 research and support staff, and 85 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, Standard Oil Company, Schlumberger, International Business Machines, Martin Marietta, Wang Laboratories, Hughes Research Laboratories, Allied Corporation, Exxon Research and Development Company, and Bendix.

ROBOTICS

Planning for Collision-Free, Compliant, and Grasping Motions

Professor Lozano-Pérez developed a new algorithm for planning collision-free motions of robot manipulators that have rotary joints. He implemented a simple, fast path planner based on this algorithm that can plan motions in crowded environments. Professor Lozano-Pérez and Mr. Michael A. Erdmann extended the algorithm to plan coordinated motions for two manipulators.

Mr. Bruce R. Donald developed and tested an algorithm for planning collision-free motions of complex polyhedral objects in a cluttered environment. This motion-planning system is the first program able to plan motions involving the three rotational degrees of freedom of a moving object, as well as the three translational degrees of freedom.

Mr. John F. Canny developed a new representation of rotation, based on quaternions, that simplifies the constraints on the motion of a polyhedral object moving among polyhedral obstacles. In the new representation, the constraints become low-order polynomials. Mr. Canny exploited the new representation to develop efficient collision-detection algorithms for polyhedral objects undergoing simultaneous translation and rotation.

Professor Lozano-Pérez, in conjunction with Professor Matthew T. Mason of Carnegie-Mellon University and Dr. Russell H. Taylor of IBM, developed a method for automatically planning compliant motions for assembly robots. The method is based on computing pre-images, the regions from which a given motion is guaranteed to reach the intended goal. Mr. Erdmann extended the approach to incorporate a detailed model of frictional interactions among objects. Mr. Steven Buckley is developing a related method of predicting the possible outcomes of a sequence of compliant motion commands in the presence of uncertainty. Mr. Michael E. Caine has done a three-dimensional analysis of polyhedral-object assembly with compliant motions.

As part of an ongoing effort to study dextrous manipulation with multi-fingered hands, Mr. Van-Duc Nguyen has been developing a theory of optimal grasps. Mr. Nguyen implemented a method for planning force-closure grasps in the plane. A force-closure grasp allows a hand to exert arbitrary forces and torques on a grasped object.
Dr. Alain F. Lanusse, in collaboration with Professor Lozano-Pérez, has been working on the problem of model-based recognition of polyhedral objects from vision or range data. An experimental geometric modeling system relying upon advanced algorithms has been implemented on LISP Machines to allow the representation of complex polyhedral solids. The definition and the exploitation of discriminating geometrical properties that could help model-based recognition also has been investigated.

Mobile Robots

One goal of Professor Brooks' mobile robot project is to investigate methods for building reliable maps of everyday environments from visual observations. Another goal is to investigate methods for building robust control systems for mobile robots that can operate, in real time, with long-term autonomy in changing, unpredictable environments. A mobile robot now under construction will have stereo TV cameras and ultrasonic range sensors on board, as well as a TV and radio link to offboard LISP Machines that provide the necessary computational power to control it.

Professor Brooks defined several levels of behavioral competence for mobile robots, and he is building corresponding layers into a robot control system: as the robot becomes more competent, more processor power is added, leaving existing processors as they are, still running, unaware of higher-level control layers. The result is a robust control system.

Professor Brooks and Mr. Sathya Narayanan have begun work on an empty vision system. The fundamental observation is that for navigation around an unknown environment it is more important to know where the navigable empty space is than to be able to identify particular objects and their characteristics. Empty vision is based on using a fast point-based stereo-vision algorithm and the visibility constraint: if a point is visible in an image then there is an unobstructed straight line between the image plane and the point in space.

Professor Brooks has extended earlier work on uncertainty propagation so that unreliable observations from multiple observation points can be combined in such a way that overall uncertainty is reduced. The technique relies on placing cylindrical bounds on the uncertainty manifolds in a robot's configuration space, and then using a simple calculus of geometric combination to do both forward and backward reasoning about uncertainty.

Professor Brooks and Mr. William Y.P. Lin have begun to look at new representations of three-dimensional objects for model-directed vision. They designed a system that can select readily-identifiable objects from visual scenes, construct a three-dimensional model, and then recognize the objects from new viewpoints. This is extremely useful for mobile robot map-making and navigation.

Identifying and Orienting Objects

Professors Grimson and Lozano-Pérez have been developing a system capable of recognizing objects using polyhedral models of known objects and information about the position and surface orientation of a few points. Their system determines both an object's identity and orientation. It deals with parts that overlap considerably. A new pre-processing step that segments the input data into groups has resulted in an order-of-magnitude improvement in speed.

Professors Grimson and Lozano-Pérez tested the system extensively, both in simulation and on real data from a variety of sensors. In addition to gathering empirical evidence concerning the system's performance, Professor Grimson developed a mathematical analysis of the combinatorics of the system that proves the power of the underlying geometric constraints. Professor Grimson also developed methods for automatically predicting optimal sensing positions for acquiring the sensory data to be used in the system.

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.

Professor Hollerbach predicts that future manipulators will be redundant, with seven or more degrees of freedom and an increased ability to avoid obstacles. With Mr. Ki Choon Suh, Professor Hollerbach examined a class of control algorithms for redundant arms that resolves the redundancy by minimizing the torque loading at the weaker joints. A surprising instability corresponding to the development of an internal whipping action was discovered for such locally optimal algorithms.
When a robot arm picks up a load, the robot should identify the inertial characteristics of the new load. Mr. Christopher G. Atkeson, Mr. Chae Ilun An, and Professor Hollerbach have formulated a least-squares parameter estimation technique that combines force readings with velocities and accelerations derived from joint angle measurements. Experiments with a wrist force-sensor on a PUMA robot indicated very good estimates for load mass and center of gravity, but mediocre estimates for inertia. Small endpoint accelerations and errors in deriving acceleration were the limiting factors.

The four-year joint project of the University of Utah/MIT hand reached a successful conclusion with the demonstration at Utah in November of a prototype hand and the imminent delivery of a duplicate to MIT. The hand, designed in collaboration with Professors Steven Jacobsen and John Wood of the University of Utah, has four fingers operated by tendons. To control the hand, Mr. David M. Siegel and Mr. Sundar Narasimhan constructed a multiprocessor system based on the Motorola 68000 and the multibus, where each finger and its eight tendons are controlled by one microprocessor.

Mr. Ignacio H. Garabieta, Mr. Siegel, and Professor Hollerbach have designed and are testing large-array tactile sensors. The arrays are defined by conductive strips screened onto thin rubber sheets. An electronic circuit detects capacitance change due to decreased distance between conductive strips from pressure deformation.

Dr. Salisbury’s research is concerned with the design, control, and programming of articulated hands as a means of increasing robot dexterity and adaptability. Fundamental to his approach is the study of the underlying mechanics of manipulation and sensing with multiple degree-of-freedom end effectors. He developed a comprehensive laboratory environment for experimentation with the Stanford/JPL/MIT three-finger hand. This includes extensive control software for commanding finger trajectories under position, force, and stiffness control, as well as analytical software for improving servo bandwidth and sensitivity.

As part of Dr. Salisbury’s research, the first level of a LISP-based hand control environment has been implemented by Mr. Stephen L. Chiu. This system permits the command of finger and grasped-object motions in arbitrary Cartesian frames of reference, with automatic determination of the correct joint motions to achieve them. It is being extended to permit the monitoring of various conditions so that hand movement can be modified upon collision or impending slip.

A second part of Dr. Salisbury’s work centers on the design of minimal sensor systems for augmenting articulated hand manipulation. Mr. David L. Brock developed and tested several robust strain-gauge sensor systems, including a six-axis fingertip force sensor.

In preparation for mounting the hand on an arm, Dr. Salisbury has begun to look at the control of locally redundant motions. Mr. Jeffrey D. Abramowitz completed an analysis of simple two-link mechanisms that suggests methods for efficiently and synergistically coordinating the joints for high-bandwidth movement.

Manipulator Control

Present day industrial robots depart widely from their commanded trajectory when asked to move fast. This is a big problem in applications such as seam welding and laying down of glue because the whole trajectory is important, not just the end point of the trajectory. Working with Professor Horn, Mr. Michael Gerstenberger completed work on a new control scheme for a direct-drive arm using a partitioned state space. The dynamic model of the arm is used to compute a feedforward term. The dynamic model is also used to determine the coefficients for a feedback loop designed to compensate for differences between the mathematical model of the arm and the actual arm.

Kinematic chains with the minimal degrees of freedom suffer from singularities in certain parts of their workspace. This is a phenomenon similar to the so-called gimbal lock in the case of gyroscopes. In both cases, the solution involves the introduction of additional, redundant degrees of freedom. Professor Horn studied the singularities and related them to several other aspects of manipulator kinematics. He isolated so-called degenerate singularities that occur for particular arm designs. Mr. Pyung Chang developed new methods for selecting one of an infinite number of solutions for a redundant arm. The new method depends on a direct mapping from Cartesian space to joint angles, as is normal in the case of non-redundant arms.

Professor Seering and his students concentrate their efforts on other aspects of manipulator control, developing methods for utilizing advanced computational capability to enhance the performance of robots. One project involves the creation of models of robot dynamic performance, including resonant phenomena, and the design of control algorithms that employ the models in real time to maximize system performance.
VISION

Laser Ranging

Dr. Philippe Brou built a new laser scanning device that produces up to a quarter of a million depth points, representing a fivefold increase over our previous laser-vision system. Dr. Brou conducted several experiments using different optical devices to increase the accuracy of the system. The system is now self-calibrating, will accept any lens type, and tolerates large errors in the orientation of the lasers.

One of the problems with such a device is that information is obtained from only one direction, thus leading to complex correlation problems for three-dimensional vision systems. Dr. Brou proposed the implementation of a multi-camera system that would obtain surface information from all sides of the object. Such a system would make it possible to generate full object models in a simple sweep, providing much more data for vision or CAD reconstruction algorithms.

Recovering Shape from Shading

The shape of a smooth surface can be recovered from a single image using the variation in apparent brightness resulting from variations in the orientation of surface elements with respect to the light source and the viewer. The original solution to the problem of recovering shape from shading, worked out by Professor Horn in 1970, required sequential solutions of the characteristic equations. Since then, there has been a search for methods that could be applied in parallel in an image in real time. This year Dr. Michael Brooks and Professor Horn developed a new iterative algorithm that can deal with occluding boundaries and that does not have the distortion potential inherent in the earlier formulations.

Using parameterized reflectance maps, Dr. Brooks and Professor Horn developed methods that determine light-source position, given a Lambertian surface. The shape of the surface is then derived as a byproduct.

In another area, Mr. Shahriar Negahdaripour and Professor Horn are exploring the use of moving images for determining the motion of an observer as well as the shapes of surfaces in the environment. Previous work by Dr. Brian G. Schunck and Dr. Anna Bruss accomplished this by exploiting the optical flow, an intermediate representation of the changes taking place in the image. Professor Horn and Mr. Negahdaripour are developing mathematical techniques to bypass this intermediate step.

The problem of direct passive navigation as stated in the obvious way is not well posed. It can be solved using the recently popularized methods of regularization. These methods work well provided that the surface under consideration is reasonably smooth. Mr. Negahdaripour implemented an iterative algorithm for solving the discrete approximations of the Euler equations resulting from the calculus of variation formulation of the problem. Using this method, he has been able to unambiguously recover the shapes of smoothly curved surfaces.

Another method stems from the obvious observation that imaged objects have to be in front of the camera. A constraint equation relates derivatives of brightness and the depth. Each such constraint equation leads to an inequality. Professor Horn is now searching for an approximate solution technique for a large set of such inequalities, given that six parameters of rigid body motion are to be found.

Shape Description

Dr. Brady and his staff continued to develop a new representation of two-dimensional shape called smoothed local symmetries. Mr. Haruo Asada and Dr. Brady implemented a fast algorithm that first locates significant curvature changes on a shape’s boundary using a process analogous to edge finding. The algorithm fits an approximation to the boundary, from which the smoothed local symmetries are computed. The representation of curvature changes is called the curvature primal sketch.

Ms. Anita Flynn adapted the algorithm to mobile robot navigation using multiple sensors. She developed rules for combining sonar and infrared sensory data to overcome the limitations of each individual sensor. The curvature primal sketch generates a set of landmarks in the resulting sensed data, and these landmarks are used to register data from successive positions of the robot. In another application, Mr. John Agapakis demonstrated a shape description of a laser stripe using the curvature primal sketch to perform in-process inspection during arc welding.

The smoothed local symmetries representation has been extended in two ways. First, Mr. Jonathan H. Connell
substantially enhanced the descriptive capabilities of the representation in a system that generates semantic network
descriptions from images. Mr. Conneli developed an algorithm that learns object models by matching such semantic
networks using an operation called ablation. He showed that ablation, applied to different data types, can achieve
many of the heuristics developed for inductive generalization. A key component of the work is the extension of
Gray coding to intervals, trees, and graphs.

Ms. Margaret M. Fleck noted that smoothed local symmetries are not well suited to representing compact, roughly
circular shapes, such as the ends of a wrench or eggplant or the sides of a lemon. She formulated a companion
representation that is based on rotational symmetries, where smoothed local symmetries are based on reflectional
symmetries. Her implemented algorithm is designed to be executed on a highly parallel processors.

Mr. David J. Braunegg's research involved extending Brady's smoothed local symmetries work for use in describing
three-dimensional objects. Two methods of generating smoothed local symmetry descriptions from depth map data
were demonstrated.

The International Journal of Robotics Research, founded and edited by Dr. Brady and Professor Richard P. Paul
of the University of Pennsylvania, was named the outstanding technical publication of 1984 by the American
Publisher's Association. Also, a special issue of the Journal on legged locomotion, guest edited by Professor Marc
H. Raibert of Carnegie Mellon University, was named the best single issue of a journal.

Early Biological and Machine Vision

Professor Poggio, Professor Ullman, and their associates are developing a theory of computational vision intended
to shed light on both biological and machine vision. The theoretical understanding of artificial vision benefits from
the study of human vision because biological visual systems provide the best-known examples of efficient visual
processors. Problems studied include regularization theory, edge detection, stereo, motion, surface reconstruction,
multigrid algorithms, the computation of color, the computation of spatial properties, the development of an
artificial eye-head system, the understanding of trajectories, intelligent signal processing, new parallel analog
hardware, and biophysics of computation.

Professor Poggio is working on many early-vision problems that are mathematically ill-posed in the sense of
Hadamard. Regularization analysis, developed in recent years, can be used to solve those early-vision problems
using variational principles that enforce constraints derived from a physical analysis of the problem. This is a
new theoretical framework for some of the variational solutions already obtained in the analysis of early vision
processes. It also shows how several other problems in early vision can be approached and solved.

Professor Poggio, Professor Vincent Torre (of the University of Genoa, Italy), Dr. Alan L. Yuille, Mr. Harry L.
Voorhees, and Ms. Anya Hurlbert applied regularization analysis to several problems in early vision, including
edge detection, color computation, and stereo matching. At the same time, Mr. Jose Marroquin, Dr. Demetri
Terzopoulos, and Dr. Yuille, continued to extend regularization theory in order to deal with discontinuities and to
fuse information from different vision modules.

As proposed by Professors Torre and Poggio, edge detection, when defined as a problem of numerical differentiation,
is an ill-posed problem. Using standard regularization theory, the problem can be regularized. The regularized
solution is then the solution to a variational principle. In the case of non-exact image data Professor Poggio, Mr.
Voorhees, and Dr. Yuille prove three things: that this variational principle leads to a convolution filter for the
problem of one-dimensional edge detection; that the form of this filter—a spline—is very similar to the Gaussian
filter; and that the regularizing parameter \( \lambda \) in the variational principle effectively controls the scale of the filter.
Mr. David Geiger and Professor Poggio are exploring the use of methods from regularizing theories for finding
the optimal value of the regularizing parameter \( \lambda \) and the connection between these methods and the scale-space
method for edge detection.

The problem of stereo vision continued to be an important focus of research. Dr. Yuille and Professor Poggio
explored constraints on the stereo matching from the perspective geometry of the imaging process and derived a
generalized ordering constraint that can be exploited in future stereo algorithms.

The computation of motion is another typical problem of early vision. Its solution is important because reliable
information about the three-dimensional structure of the environment is encrypted in the relative movement
between features in the changing two-dimensional image that is projected onto the eye. Dr. Ellen C. Hildreth and
Dr. Norberto M. Grzywacz have designed and tested computer algorithms that can recover the three-dimensional
structure of both rigid and nonrigid objects in motion. These algorithms are extensions of previous work by
Professor Ullman.
Dr. Terzopoulos studied the computation of visible-surface representations, another ill-posed problem of early vision. A variational principle was developed which governs the reconstruction of dense visible surfaces from sparse, local three-dimensional shape estimates collected from multiple visual modules.

Another problem that is presently approached with regularization techniques is the computation of spectral reflectance of surfaces. A basic goal of biological color vision is to recover the invariant spectral reflectance properties of an object’s surface. Ms. Hurbert and Professor Poggio are developing a regularization algorithm in which two constraining assumptions allow the decomposition of the intensity array into surface reflectance and source illumination: the single source assumption, which states that the spatial variation of the source illumination is the same for each wavelength channel; and the spatial regularization assumption, which states that the spatial variation of the effective source illumination is slower than that of the surface reflectance.

The theoretical framework, based on the concept of ill-posedness of early vision, shows clearly not only the attractions but also the limitations that are intrinsic to the standard Tikhonov form of regularization theory. The main problem involves the degree of smoothness required for the unknown function that has to be recovered. Mr. Marroquin and Professor Poggio have developed extensions of standard regularization for the problem of preserving discontinuities in the reconstruction of surfaces from depth data.

Unconventional analog computational machines for solving the variational problems of standard regularization are being explored by Dr. Christof Koch and Professor Poggio. This work is closely connected to the area of biophysics of computational systems, a new theoretical approach aimed at understanding the computational mechanisms used by nervous systems. The work being carried out by Professor Poggio, Dr. Koch, and others has already shown that single neurons are likely to be very highly parallel devices performing hundreds of independent analog operations on their inputs.

The Interface Between Vision and Motor Control

Another important area of research is the frontier between visual perception and motor control. Ms. Katie Cornog, with Dr. H. Keith Nishihara and Professor Poggio, studied the computational problems related to eye-head coordination by building an artificial eye-head system provided of two stereo CCD cameras. The requirements for such a system are not unlike those for the primate oculomotor system: to scan the visual environment, locate, and fixate objects of interest; to stabilize the images of such objects despite object or self movement; and to reduce the bandwidth of visual information by the use of a small, high-density photoreceptor array which requires sequential relocation to different spots in a wide field of view.

Mr. Bror Saxberg studied another computational problem at the interface between vision and motor control. In particular, he looked at how gravity can be used as a constraint in the case of a free-fall trajectory projected onto an image plane by central projection. He has also checked for similar processing by the human visual system by looking at results from a simple video game designed to test if we are able to use the same kinds of information suggested by the theoretical implementations.

NATURAL LANGUAGE

Professor Berwick and his students are developing a computationally-grounded theory of sentence processing and language acquisition. The goal is to understand how the natural constraints of human language processing can be efficiently embedded in computer models, both to understand how people use language and to build better natural language interfaces.

During the past year, a new representation for natural language parsing based on set representations rather than on conventional tree structures was implemented and tested by Professor Berwick and Mr. Sandiway Fong. The set-based representation has proved particularly appropriate for analyzing conjunctions, traditionally considered difficult for natural language processors. The resulting parser is highly modular and easy to use for both parsing and language generation. Detailed comparison of this new system with existing parsers is underway.

Mr. Edward Barton and Professor Berwick continued research to embed the representations of current grammatical theory directly into parsers. Existing natural language parsers use derived predicates that often do not reflect the constraints of linguistic theory. By translating the predicates of grammatical theory directly into parsing models, this work hopes to exploit the constraints of that theory. The result should be more modular parsers, easy to change from language to language.

The computational complexity of several grammatical formalisms was investigated. Mr. Barton, working with Professor Berwick, showed that context-free grammars with unordered right-hand sides, a formalism thought to be computationally tractable, is in fact NP-complete and hence intractable in the worst case. Mr. Eric Ristad showed that a related context-free formalism is NP-hard, while Mr. Barton demonstrated that yet another system, used for morphological analysis and thought to be computationally efficient, is actually NP-complete.
A key part of all these modern theories of language is the dictionary, or lexicon. The word acquisition model developed two years ago has been confirmed by recent psychological studies of child word acquisition. Work was begun to extend that model to the learning of words in other, quite different languages, such as the Australian language Warlpiri. This research should lead to a better understanding of the common conceptual representation for words used by all languages and so tell us what representation computers should use.

Ms. Bonnie J. Dorr is working with Professor Berwick on a principle-based computational model of natural language translation. She developed a modified version of the Marcus Parser to handle Spanish input sentences. She also investigated the common universal principles and parametric variations across different languages so that these might be installed into a computerized translation system within the Marcus framework.

A summary of several years of research by Professor Berwick on a computer model of language acquisition was published in the MIT Press series on Artificial Intelligence as *The Acquisition of Syntactic Knowledge*.

**LEARNING**

Professor Winston's theory of reasoning by analogy consists of the following parts: an English-understanding module, developed by Mr. 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. Peter Andre completed work on a theory of procedure learning. Using elaborate matching techniques, governed by simply-stated generalization principles, he built a robot-oriented learning system that acquires simple two-dimensional movement-and-fetch programs from demonstration sequences.

Mr. Richard Doyle is developing a learning system that constructs causal models of physical devices such as cameras, showers, and toasters. Given a sequence-of-events description of the external, observable behavior of one of these devices, Mr. Doyle's learning system will construct a description of the device in terms of causal relations which account for behavior. The representation used by the system will use a vocabulary with terms like *medium*, for the structural link between objects in a causal interaction, and *barrier*, for a way of potentially negating a causal-interaction link.

Mr. Robert Hall is using analogy with precedents in work on explanation and design. He is focusing his thoughts by implementing a program that both explains existing gear-and-pulley mechanisms and designs simple new mechanisms. In the explanation direction, recognized and previously understood substructures enable functional description using a structure-function library. In the design direction, specified function enables the retrieval of suitable substructures from the same structure-function library.

Mr. Richard Lathrop is studying the role of abstraction in learning and reasoning. He implemented a program that converts a highly detailed room-and-thermostat model into more and more abstract, less and less detailed descriptions, ending with a simple feedback loop. The collection of intermediate and end-point descriptions is reminiscent of multiple-scale image descriptions in vision work.

**REASONING AND PROBLEM SOLVING**

Mr. David A. McAllester produced a reasoning utility package that is now in use in Dr. Rich and Dr. Waters' Programmer's Apprentice Project, Mr. Reid Simons' project on simulating geological processes, and in several other projects at MIT and elsewhere. The package has programs for doing simple deductions, recording justifications, tracking down assumptions, and performing modifications as premises are changed. Mr. McAllester also developed a system for verifying mathematical arguments in a wide variety of mathematical domains. The inference mechanisms underlying this verification system are based on an extension of the reasoning utility package.

Mr. John Batali is developing a computational theory of practical reasoning. He observes that the problem of determining the right thing to do is itself a problem for which an appropriate solution must be found. A theory of practical reasoning therefore must account for the actions taken to determine how to solve a problem as well as the actions taken to solve the problem itself. A single representation for programs, situations, plans, histories, and the process of deliberation is under development. This representation will be used to describe the goals and abilities of a rational agent and the progress of such an agent as it constructs and executes plans. The goal of Mr. Batali's research is to produce a theory accurate and complete enough to permit the construction of a computational system whose behavior is as the theory describes. The system will make use of an explicit representation of the theory of practical reasoning in its deliberations—it will decide what to do on the basis of what the theory of practical reasoning says it ought to do.
Mr. David Chapman has applied the techniques of the formal theory of computation to artificial intelligence research in plan generation. Nonlinear constraint-posting is the most promising approach to planning; previous planners of this type have been complicated, heuristic, and ill-defined. Chapman has combined and distilled the state of the art into TWEAK, a simple, precise, implemented algorithm, which he has proved correct and complete.

Mr. Kenneth W. Haase is working on programs that demonstrate expertise in multiple domains. Such systems use a variety of methodologies and representations to perform in various domains, customizing and extending their capabilities as new domains are described and explored. Unlike most systems, which typically are limited to a single approach in a single domain, these eclectic problem solvers move from approach to approach and domain to domain as new problems and situations present themselves. The development of eclectic problem solvers draws on the large body of existing problem-solving and learning technology, attempting to build a unified framework for describing and implementing reasoning and acquisition technologies.

DEEP EXPERT SYSTEMS

Professor Davis, Dr. Shrobe, and their associates are building an expert system that uses knowledge about structure, function, and causality to diagnose faults in digital electronic hardware. Previous 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 the device under test, 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 is aimed at computer diagnosis because of its familiarity and the significance of the problem, the larger concern is that of 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), test generation (designing tests to distinguish between candidates), and diagnostic generation (designing a comprehensive collection of tests that verify correct device operation).

The 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.

Mr. Walter 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 under-constrained, and he explored the utility of several different behavioral abstractions as ways of constraining the problem.

Mr. Harold 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.

Mr. Mark 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 patterns of usage 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.

Mr. Brian 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.

Dr. Fanya O. 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. One specific example arises in the dual problems of schematic capture and schematic generation, where we want to describe circuits to the system by drawing pictures, and where we would like to have the system determine how best to display a schematic when working from the topological description provided by our representation.
Mr. Raul Valdes-Pérez has been working on a knowledge base for schematic generation, assembling a knowledge base of drafting techniques employed by experienced draftsmen, and determining the appropriate computational techniques for putting that knowledge to work. The result will be an automated draftman's notebook, containing both standard drawing techniques and more sophisticated knowledge of pictorial information presentation.

Two other projects form a second component of Professor Davis' expert-systems work. First, Mr. Simmons is working on reasoning about geologic processes. This effort is aimed at developing a program that understands and is capable of reasoning about geologic processes responsible for formations and deposits. Second, Mr. Daniel Weld has been working on the unification of 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. A program called PEPTIDE has been developed for reasoning about change. PEPTIDE uses a technique called aggregation to unify the two types of models, allowing both to be used when performing qualitative simulation, thereby allowing a simulator to switch back and forth between different types of models depending on which is most expedient.

COMPUTER-AIDED PROGRAMMING

Dr. Rich and Dr. Waters study how expert programmers analyze, synthesize, modify, explain, verify, and document programs. A long-term goal of this research is to develop tools that automate the programming process. Recognizing that total automation is not close, they are developing a system called the Programmer's Apprentice, which acts as an intelligent assistant to an expert programmer. The Programmer's Apprentice will begin by automating the more routine, straightforward parts of the programming task, leaving more of the programmer's attention free to concentrate on the difficult decisions.

Dr. Waters recently completed a technical report documenting the use of the Knowledge-Based Editor in Emacs (KBEmacs) to construct several 50-to-100 line programs in LISP and in ADA. KBEmacs demonstrates a first step towards the Programmer's Apprentice by providing a vocabulary of knowledge-based commands in which these programs are described using an order of magnitude fewer lines than the resulting code. Also in this demonstration, the Knowledge-Based Editor is closely integrated with the Emacs-type program editor in the Laboratory's LISP Machine programming environment. As a result of this integration, a programmer can intermix ordinary text editing, syntax-directed editing, and knowledge-based editing, using whichever is more convenient at a given point.

During the past year, Dr. Rich has become interested in issues in the design of hybrid knowledge representation and reasoning systems. This interest has been motivated by the continuing development of the Cake system, which will form the basis of the next phase of development of the Programmer's Apprentice. Cake is a hybrid system with two major layers. The bottom layer is a predicate-calculus inference engine evolved from the reasoning utility package of Mr. McAllester. The top layer of Cake is an implementation of the plan calculus, a flowchart-like representation of program structures developed as part of the Programmer's Apprentice project. The Cake architecture attempts to apportion reasoning tasks between the two layers so as to increase the overall effectiveness of the system.

INTELLIGENT SUPERCOMPUTING

The Cross-Omega Connection Machine

The Cross-Omega Connection Machine is a computer that performs fast, parallel searches through networks, a fundamental, rate-limiting step in many problem-solving programs. Led by Professor Knight, work on this machine is a major effort undertaken in collaboration with the General Electric Company.

A prototype machine has been designed, a packaging scheme selected, and implementation of prototype hardware begun. Because the design requires parts to be duplicated in great numbers, yield, testing, packaging, and reliability are receiving careful attention. The large scale of the project forces the development of new methodologies and design tools.

Mr. Alan Bawden utilized applicable parts of conventional compiler technology to implement a prototype language for programming massively parallel machines such as the Cross-Omega Connection Machine. The resulting language is still simple, but serves as a convenient basis for extension languages that support higher-level models of the machine.

Initial experiments with this language revealed common programming practices and principles that will help to design future languages. Mr. Bawden is working on a successor to this prototype language whose compiler will have a better understanding of synchronization techniques so as to relieve the programmer of some of the burden of dealing with synchronization himself.
The Apiary

The Message-Passing Semantics Group, under the direction of Professor Carl E. Hewitt, is developing the foundations for large-scale parallelism in the context of open systems. Open systems are subject to continual growth and interaction with the outside environment. Professor Hewitt's actor model provides a suitable basis for developing open systems because it supports dynamic reconfigurability, compositionality, and extensibility.

Professor Hewitt and Dr. Gul Agha have 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. Mr. Thomas Reinhardt has been integrating description systems into a unified actor language. When completed, the new language will provide linguistic support for intelligent systems in real time. A compiler will be bootstrapped with a minimal actor instruction set as the target language. Mr. Carl Manning has extended a transaction recording mechanism to support real-time debugging in a distributed environment. The mechanism allows computation paths to be reconstructed and examined in terms of the abstractions of the source programs.

Mr. J. Scott Penberthy developed a graphic presenter for a knowledge representation language called OMEGA, which incorporates features such as semantic descriptions, inheritance, quantification, negation, and contradiction handling in the context of multiple viewpoints. Mr. Oren Etzioni implemented a sponsorship mechanism for the dynamic allocation of resources in a distributed, continually evolving environment. Mr. Peter de Jong improved the performance of the SCRIPTER programming language that integrates message passing and LISP.

Mr. Henry Lieberman is investigating techniques for constructing menu-driven graphical user interfaces, using the object-oriented approach of the actors formalism. His work on an interpreter for a language of menu commands and graphical objects aims to make the construction of modern interfaces using windows and pointing devices as easy as those which use only text and typing. Mr. Lieberman's Tinker system permits a programmer to instruct a machine by example, demonstrating the steps of a new procedure on typical test cases.

MUSIC COGNITION

Professor Minsky's Music Cognition Group investigates the cognitive foundations of musical behavior using the methods of Artificial Intelligence. The general objective is to extract and represent expert knowledge about music by building computational models of the cognitive processes involved in composing, performing, and listening.

Mr. John W. Amuedo has been investigating algorithms for estimating the fundamental periodicity of superimposed quasi-periodic signals. These algorithms can be used for transcribing music from audio recordings, for recovering signals buried in systematic noise, and for separating acoustic signals which have been additively combined.

Mr. David A. Levitt models musical expertise in several styles of jazz piano. His goal is to show how left-hand patterns and melodic elaborations are learned from increasingly complex examples. In an early project, Mr. Levitt's IMPROVISER program assembled musicians' commonsense structural descriptions of a tune and used them to construct original improvisations that satisfy jazz harmony and other constraints.

Mr. David M. J. Saslav has been developing a computational theory of harmony/mode correspondence. The goal of this theory is to predict a most likely scale or mode that implies each chord in the harmonic plan of an analyzed piece. This task is an essential subproblem of expert musical composition, and is a prerequisite for generating variations automatically from a supplied harmonic plan.

Mr. Marc E. Schaedle is developing a LISP-Machine-based editor for manipulating common-practice musical notation. Western music has a complicated notation system embodying hundreds of syntactic and graphical conventions. These conventions govern both the well-formedness of musical strings to be displayed, and the placement, orientation, and alignment of symbols on the printed page. Composers and arrangers spend a considerable portion of their time dealing with issues of layout and typography, many aspects of which could be easily automated.

The Music Cognition Group began a joint research project with the Bosendorfer Piano firm of Vienna, Austria, to develop a state-of-the-art recording piano that uses digital storage media.

PATRICK HENRY WINSTON
The rapid pace of technological advance and accelerated international competition have increased general interest in continuing education for engineers in four different ways:

1. The Advanced Study Program—under which engineers in professional practice, teaching or technical management come to the Center for a semester or a year of individualized study or for special programs.

2. The Video Course Program—which through over 1000 videotaped lectures brings technical information to approximately 50,000 technical people each year.

3. The Conference and Seminar Program—which develops short courses, workshops, and seminars for practicing engineers to study subjects intensively for short periods of time.

4. Through integrated offerings of the Center in which all three portions of the Center participate by focussing their efforts on a particular problem of interest to industry.

**Advanced Study Program**

This is an on-campus program that enables engineers and scientists to work in depth in technological areas of their choice. The program serves technical managers who wish to understand developments that bear directly on their problems, men and women who seek competence in depth at technological frontiers, and those who desire to strengthen their technological base. This year there were 67 Fellows from 15 countries. Forty-two percent of the participants were from the United States.

Fellows of the program are affiliated with the Center for one or more terms. They may develop courses of study to meet their individual needs or may participate in specialized programs. Included in ASP are several specialized programs such as Air Transportation, Systems Reliability and Risk Analysis, Quality and Productivity, Communications Technology and Policy, and Design and Manufacturing Automation and Control, as well as the Visiting Engineer Program. The Visiting Engineer Program is similar to ASP except that the emphasis is on participation as colleagues in research with faculty members.

The programs coincide with the normal academic terms and year. Special weekly seminars are planned and conducted during the fall and spring terms especially for Fellows of ASP and participants in the Visiting Engineer Program. Each term several special subjects of broad interdisciplinary interest are also offered within the Center for participants in the programs.

Grades are recorded for all MIT subjects taken for credit. A certificate is awarded following satisfactory completion of a Program. Fellows also may apply for admission to the MIT Graduate School. The Advanced Study Program (ASP) is directed by Dr. Paul Brown.

**Video Course Program**

Video Course development continues strongly. Several new subjects were published during the period, among these: Fluid Dynamics, by Professor Ascher H. Shapiro; VLSI CMOS Circuits, by Professor Jonathan Allen; and Electronic Feedback Systems by Professor James K. Roberge. Signals and Systems, by Professor Alan Oppenheim; and Statistics in Quality, Productivity, and Problem Solving, by Dr. Lloyd S. Nelson are scheduled for publication in late 1985.

The following courses are scheduled for production in the second half of 1985: Composite Materials, by Professors James W. Mar and Paul A. Lagace; and Finite Element Methods in Engineering Mechanics - NonLinear Analysis, by Professor Klaus-Jurgen Bathe.

The courses listed above will add approximately 134 videotapes to MIT's extensive library of video-based continuing education subjects. In addition, each course is accompanied by a comprehensive manual.

The staff of MIT Video Courses manages all aspects of videotape and book production, from market research and concept development through production, marketing, and client support. Continuous attention to training, education, and implementation of new technologies results in a professional staff that is well equipped to work closely with client organizations.
New course development in all engineering disciplines is progressing vigorously. We continue to meet with Department Heads to determine the needs for video courses in each discipline. Course development proposals benefit from the review and consideration of the Video Publishing Advisory Committee, comprised of faculty members from each department. Over one hundred new videotapes will be developed during fiscal year 1986. The Video Course Program is under the direction of Richard J. Noyes.

Conference and Seminars Program

The Conference and Seminar Office was established in 1977 to provide professional and logistical support for the growing number of technical continuing education conferences, seminars, and noncredit short courses at MIT. While the majority of programs offered through the Seminar Office originate in the School of Engineering, the Seminar Office is prepared to handle continuing education programs from any area of science and technology and is designed to manage these programs on and off campus -- in the United States and throughout the world. The Seminar Office has received the approval of both the Engineering Council and the Academic Council as a recognized office of continuing education at MIT.

The Conference and Seminar Office manages every aspect of the program from concept through post-meeting evaluation. This includes program development, marketing, logistics and financial management. This professional attention has resulted in a yearly increase in programs. People from more than 49 states and 36 countries have participated in the continuing education offerings from the Seminar Office.

The heavy demand for continuing education offerings has resulted in a growing number of programs at MIT. Some of the 1983-84 programs included: "Finite Element Theory and Practice", sponsored by the Department of Mechanical Engineering; "Thermal-Hydraulic Design and Safety for Light Water Reactors", sponsored by the Department of Nuclear Engineering; "The Special Studies Program in Transportation", a series of meetings sponsored by the Center for Transportation Studies; "Managing Systems of People and Machines for Quality and Productivity", sponsored by the Center for Advanced Engineering Study; and "Methods for Nonlinear Finite Element Analysis", sponsored by the Department of Mechanical Engineering. The Conference and Seminars Program is directed by Christine Simonsen.

INTEGRATED OFFERINGS BY THE CENTER

For the last three years the Center has focussed efforts on helping industry to increase quality and productivity in domestic and international commerce. This work has involved all three activities of the Center in coordinated programs.

The videotapes of W. Edwards Deming have been augmented by tapes prepared by the Director aimed at showing how to reduce Dr. Deming's approach to practical methods. Tapes of actual cases have been prepared. Tapes on statistical methods have been made.

Thirteen conferences have been held at eight locations where 1,418 people were introduced to Deming's methods and their application.

The Advanced Study Program developed a special 15 week program built around a special subject, "Managing Systems of People and Machines for Quality and Productivity", offered by CAES, the Department of Mechanical Engineering and the Sloan School jointly.

Three years ago the Center called a meeting of representatives of industry, government and academia to determine what ought to be done to help spread the education on quality and productivity management. Out of this effort there was born the American Quality and Productivity Institute, a not-for-profit organization with headquarters in the new building of the National Society of Professional Engineers (NSPE) in Alexandria, VA. The NSPE, the American Society for Quality Control, the American Association of Community and Junior Colleges, the American Statistical Association and other societies have either joined or indicated their intention to do so. In early June the 500 Chapters of the NSPE were asked to start local "Quality Councils" which will be support groups for local educational efforts built around local community college courses sponsored by AQPI and the AACJC. Local support groups will be in communication through electronic bulletin boards now established on the MIT MULTICS program. It is intended that the entire system will be moved to the control of AQPI headquarters. Meanwhile, the work is coordinated on a national scale from CAES.

MYRON TRIBUS
The Center for Policy Alternatives (CPA) is dedicated to both research and education in science and technology policy. Professor Nicholas A. Ashford has served as Director of the Center since 198-. Founded in 1972, CPA has been presenting alternative courses of action to government, industry, labor, and educational concerns that are addressing complex socio-technical problems. CPA has been concerned with both industrial innovation -- the way new technology is developed and introduced -- and with technology's effect on society.

CPA's objectives are to identify and study important emerging social issues in which science, technology and engineering play a significant role, to assess the consequences of established institutional policies and develop alternatives available to decision makers, and to provide faculty, research staff, and students with research and training opportunities in policy formulation and analysis. The Center especially welcomes the participation of faculty, students and staff from other departments, centers, and laboratories in joint research efforts.

CPA faculty and staff are active participants in the Technology and Policy Program (TPP) in the School of Engineering. The Center continued to strengthen its association with the TPP program through an informal seminar series jointly sponsored by CPA and TPP, the provision of research space and supervision of a substantial number of TPP students at CPA and the commitment of research funds to support research assistance sufficiently in advance of their entrance in order to attract them to the Program.

The CPA approach to policy analysis is multidisciplinary, involving specialists from a wide variety of backgrounds, including science, engineering, law, economics, political science, and philosophy. Research at the Center often requires the development of new research methodologies that both encompass and extend traditional methods. Legal analysis is an important dimension of the Center's work, and law and technology courses at MIT have been developed and are taught by Center faculty and staff.

Many CPA studies are international in scope and use a comparative approach, or focus on the experience of a single foreign country, often with the collaboration of foreign research centers or universities. CPA research reports and publications are distributed to leaders in government, industry, labor, education, public interest groups, and to other research centers throughout the world.

During the past year CPA continued its specialization in technology and industrial policy; telecommunications and information policy; regulation and technological change; environment, health, and safety regulation; issues related to technology, labor and the consumer.

As of July 1, 1985, CPA will be incorporated into an expanded policy center at MIT entitled the Center for Technology, Policy, and Industrial Development, under the direction of Professor Daniel Roos. The new Center will also incorporate the Masters Degree Program in Technology and Policy and will bring together students, faculty and research staff in a newly integrated fashion.

RESEARCH

Technology & Industrial Policy

Dr. Nancy Dorfman concluded her NSF-sponsored study of innovation in the computer and the semiconductor industry. The study aimed at laying the groundwork for a theory of the relationship between market structure and innovation that could explain the conditions under which new or small enterprises, in contrast to large established companies, play leading and even dominant roles as innovators.

Professor Marvin Sirbu continued his research project on the determinants of computer and communications standards. This research project develops and tests a theory which explains the process by which compatibility and variety-reduction standards are invented, developed, promulgated, adopted, and enforced. Decisions by individual firms to support standards are treated as a problem in technology development and market strategy. The goal is to account for when and why standards are adopted and to understand the relationship between standards and the structure of information markets.
Telecommunications and Information Policy

The future of societal development and information technology are closely related. Some countries such as France and Japan have established a cultural commitment to new information systems because of these relationships. Dr. Curtiss Priest is currently determining the scope and feasibility of a program on Technology, Information and Societal Development. The effort would have strong ties with the Office of Technology Assessment Division on Communications and Information Technology as well as the MIT Program on Communications Policy and the MIT Media Laboratory.

Charles C. Caldart, Esq., Dr. Dale Hattis, and John Wasson, a TPP student, completed for the Environmental Protection Agency an extensive evaluation of the data management system underlying the agency's pesticide and toxic substance programs. They found that the current system was not addressing EPA’s needs adequately, and they recommended a series of strategic modifications designed to strengthen the enforcement programs for pesticides and toxic substances.

Dr. Priest and Professor Caroline Whitbeck have been examining the effects of new information and communications technology on values. Their study addresses how standards of association can be maintained or improved when the form of communication undergoes rapid technological change, how the restructuring of information flow can achieve human welfare goals; and what new rights, obligations, and responsibilities will result from the adoption of new information technology. Current focus is on values critical to the design of computer information technologies in medicine.

A computer teleconference was conducted in the Spring of 1985 in which twenty prominent physicians, health care professionals, sociologists, philosophers, and medical decision-making designers participated in identifying alternative designs for medical information systems. A summary of the teleconference has just been published.

Dr. Priest has been participating in a major Office of Technology Assessment study on Intellectual Property. In one contribution to the Congressional study, Dr. Priest investigated the Character of Information and how the characteristics and properties of information relate to issues concerning intellectual property.

Regulation & Technological Change

The NSF-sponsored study of innovation in the pharmaceutical industry was completed and is an in-depth analysis of three therapeutic areas to reveal associations between specific kinds of regulatory and non-regulatory stimulus conditions, drug development process types, and innovative progress. A data base has been compiled for the period 1950-1981 to analyze trends in drug innovation. Examining three therapeutic classes of drugs to isolate the changing patterns of drug innovations which are attributable to regulatory influences after 1962, Dr. Hattis, project manager, Professor Ashford, principal investigator, and the research team have found that there are fewer new drugs appearing, but they are of greater therapeutic value than those appearing prior to 1962.

Professor Ashford and Robert Stone completed a review of the methodologies for assessing the effects of regulation on technological change in the chemical industries for the OECD.

Environmental, Health and Safety Regulation

A major effort was undertaken to build a framework for risk assessment of genetically engineered organisms. Reports completed during the year in the genetic engineering area included (1) an analysis of the extent of current industrial innovation that is based on the use of undirected mutagenesis techniques in microorganisms, and (2) a comparison of expected releases of microorganisms in greenhouse testing with the releases that can be expected in the course of ordinary laboratory research and development (using different specified containment measures in each case. Dr. Hattis, Dr. Harlee Strauss, Dr. Guy Page, a number of graduate students, and faculty from other MIT departments have been involved in this work.

Another important focus of the group is the development of improved techniques for quantitative health risk assessment. Projects in this area include (1) building integrated pharmacodynamic models to better predict the carcinogenic activity of two-carbon alkylating agents (e.g. ethylene dibromide, ethylene dichloride, vinyl chloride), (2) determining the likely effects of human interindividual variability on population dose response relationships for both carcinogens and more conventional toxic agents. Early efforts were also undertaken to develop risk assessment models that would be appropriate for reproductive hazards. Dr. Hattis and Dr. Strauss are leading these projects.
Dr. Hattis and Thomas DiMauro conducted a study of the health benefits and costs of supplementary measures to improve compliance with workplace exposure limits for asbestos in the construction industry.

**Technology, Labor, and the Consumer**

The Office of Technology Assessment of the U.S. Congress has been focusing much attention on policy issues concerning the relationship between technological change and employment. CPA completed one study in this area for OTA in September 1983 and is currently completing another. This is a study of the expenditure and employment effects of health, safety and environmental regulation. Conducted by Dr. Andrew Martin, it is part of OTA's project on Technology and the American Economic Transition. It traces the relationships between policy developments and the economic activities generated in response to them.

Dr. Priest has been participating in an Office of Technology Assessment study on Engineering Manpower. To better determine the problems associated with manpower availability, he conducted an in-depth survey of twenty firms, universities, and placement agencies in the Boston - 128 region. Dr. Priest found that there is still a serious problem with the obsolescence of engineers and suggests that better information policy regarding know-how systems may help solve the problem.

**EDUCATIONAL ACTIVITIES**

Students perform a major role in CPA research and are involved in most projects undertaken by CPA. Many of the MIT graduate students who work at CPA are Masters candidates in TPP. Professor Ashford and Professor Sirbu served on the TPP Faculty Steering Committee. Professor Whitbeck participated in the Pro-seminar. CPA has as its first educational priority to establish a stronger coupling with TPP. The center has increased its role in guiding the Program, provided space for approximately one-half of the TPP students, sponsors joint seminars between the CPA and TPP students, and commits funds to the support of research assistants sufficiently in advance of their entrance in order to attract them to the Program. CPA will continue these activities, as well as the supervision of theses and assistance to the TPP graduates in securing policy-related employment.

CPA is one of several centers at MIT which contributes to the collaborative effort of the Research Program in Communications Policy. Graduate students develop their own interdisciplinary course of study through the Program in Technology and Policy, or through other departments, including Electrical Engineering and Computer Science, Economics, the Sloan School of Management, and the School of Architecture and Planning. Professor Sirbu teaches a joint EECS-Political Science course 6.933J Telecommunications Technology and Policy. CPA now houses research assistants in Communications Policy and provides an Institute focus for students in this area.

**INFORMATION DISSEMINATION**

CPA Bibliographic Management System (BMS), a computer-based storage and retrieval system designed by Dr. Priest and based on the FOCUS data-base management system, is now in its fourth major version. It contains 14 substantive bibliographies; innovation, toxic substances, regulation, benefits, values, transportation, trade secrets, medical, reindustrialization, chemicals, lead, and well-being. Interests in this powerful research tool, which organizes and searches bibliographic material and generates bibliographies, continues to grow within CPA and the larger MIT community, as well as outside of the Institute. BMS is now being used by MIT's Technology Adaptation Program and by the Aga Khan Program for Islamic Architecture. BMS software is available from MIT.

**VISITING RESEARCH STAFF**

Professor Cristiano Antonelli, of the University of Calabria in Italy, has been a Rockefeller Fellow at CPA. He has developed papers on the diffusion of modems and data communications and the impact of telecommunications on multinational corporations and international trade.

Dr. Stephanie Bird continues her joint appointment with the Science, Technology, and Society Program, from a Mellon Foundation fellowship. Her research at CPA, which will last over several years, will focus on the ethical aspects of premenstrual syndrome.

Mr. David Allen, a member of the MIT research program on communications policy, is the project director of a videotex database survey. The survey is compiling descriptions of original databases in this sector to evaluate their potential for general business and home use.
Professor Beth Mintz, from the University of Vermont, spent her sabbatical at the Center while writing on issues of the effects of computers.

Bjorn Engaas from Norway spent the year at CPA working on cross-national comparisons of regulation policy.

NICHOLAS A. ASHFORD
The Center for Transportation Studies was founded in 1973 to stimulate and coordinate transportation research and education at MIT, and to develop working relationships with the transportation profession. Since its beginning, the Center has conducted nearly $15 million of research involving all transportation modes in both the public and private sectors. The Master of Science in Transportation Program has graduated 84 students since 1979, and our continuing education programs bring in nearly 100 mid-career professionals every year.

Executive Committee. The Center has working relationships with over 60 faculty members from ten departments at MIT. Direction is provided by the Executive Committee, made up of faculty representatives, which included the following members in 1984/85: Professor Ralph Gakenheimer (Urban Studies & Planning), Professor Jerry Hausman (Economics), Professor Thomas Magnanti (Head, Management Sciences Area, Sloan School of Management), Professor Amedeo Odoli (Aeronautics & Astronautics), Professor Daniel Roos (Director of the Center), Professor Robert Simpson (Head, Flight Transportation Laboratory), Professor Nigel Wilson (Head, Transportation Systems Division, Civil Engineering) and Professor David Wormley (Head, Mechanical Engineering).

Change of Leadership. In June, Daniel Roos, Director of the Center, became the first Director of MIT's newly-formed teaching and research Center for Technology, Policy and Industrial Development. The appointment was a natural outgrowth of his leading role in major research efforts in technology and policy, most recently as co-director of the International Automobile Program. Dr. Roos will of course remain closely allied with the Center for Transportation Studies. Gerard McCullough, previous Deputy Director, is serving as Acting Director.

RESEARCH

In 1984/85, the research budget of the Center totalled $1.3 million and included 28 projects involving 19 faculty members from six academic departments and centers.

International. In September, the Center sponsored a symposium at MIT to reveal the findings of the International Automobile Program, a massive four-year undertaking conceived and directed by the Center. The meeting was one of three international meetings held last fall -- the others in Tokyo and Berlin -- to announce the findings of the study, and marked the publication of The Future of the Automobile, which was named among the ten best books of the year by Business Week. An extension of the auto program -- officially titled the International Motor Vehicle Program -- is now being formed to include more participants and to examine the future of trucks as well as of automobiles. That program will be carried out in conjunction with MIT's new Center for Technology, Policy and Industrial Development.

Regional. In conjunction with the MIT Center for Construction Research & Education, we have started work on the formation of a New England Transportation Consortium, a formal collaboration among the six New England state governments and their universities to address the problems they share in rebuilding their roads. While there have been collaborations on individual projects before, this is the first attempt in the nation to establish an ongoing collaboration of this sort, and as such, it has the potential for providing one of the most innovative and cost-effective research programs ever carried out by state highway and transportation departments. We also started a project with the Massachusetts Department of Public Works to update its maintenance management system and help with applying it.

Logistics. The Center is currently undergoing a major expansion of its transportation logistics efforts, much of which involves the collaboration of the MIT Operations Research Center. New efforts include the development of a new concentration area in transportation logistics, the formalization of an ongoing series of works-in-progress workshops, the planning of an international symposium on the state-of-the-art in operations research theory, and computer linkages between the Transportation Computation Laboratory and the computer resources of the Operations Research Center. As part of this new direction, we also began a project with Gillette to develop for them a new computer-based logistics planning system to optimize the cost and efficiency trade-offs between their transportation and inventory systems.

EDUCATION

This year, ten students received the Master of Science in Transportation in June, forty-two professionals attended our 1984 summer program, and 25 are scheduled to attend our Executive Program in August.

The Master of Science Program. Incoming students were offered two new transportation courses last fall: "Highway Design, Construction, Maintenance and Operation" included all the basic elements of design, construction and maintenance, but differed from traditional courses in its emphasis on the interrelatedness...
of those various aspects and on the need for innovative analysis techniques involving computer simulation and optimization procedures. "Transportation and Infrastructure in Developing Countries" focused on planning procedures, maintenance and repair, and technology, and was designed to give students a framework for the analysis and planning of transportation, water supply, sewerage and other services in developing countries, especially urban areas.

The Special Studies Program in Transportation. The Special Studies Program in Transportation offers professionals the opportunity to remain abreast of new developments and to acquire new techniques specific to their needs. Begun as a one-week course in the summer of 1969, the program has evolved into a package of several subjects offered over a three-week period each year. In the summer of 1984, the courses offered were:

- Logistics Analysis for Carriers and Shippers
- Microcomputer Applications in Transportation
- Public Transportation Service and Operations Planning

The Executive Program in Transportation. The Executive Program in Transportation is a joint effort of the Center for Transportation Studies and MIT's Sloan School of Management. The program is one of several executive programs at MIT, including the Sloan Fellows Program and the Sloan School's Senior Executive Program, as well as the Special Studies Program in Transportation and the Summer Program in Air Transportation. This year's offering, slated for August, is entitled 'Logistics Analysis For Carriers and Shippers' and offers carrier representatives a firm foundation in logistics analysis as it is currently used by shippers, as well as offering shipper representatives a better understanding of the transportation aspects of the overall logistics scheme.

AFFILIATES

The Affiliates Program was established to encourage the growth and development of research and education relationships between the Center and organizations in the private sector. The program came under new leadership in the fall when Gerard McCullough was appointed the Center's new Deputy Director in charge of the Affiliates Program, and the program's membership was enhanced this year by the addition of The 3M Company, an international organization with operations in 52 countries.

Forum. In June, about thirty decisionmakers from as many organizations convened at MIT for a forum on the future of transportation, focussing on four especially important sets of changing relationships and boundaries -- between carriers and their customers; national and international markets; capital, labor and management; and the public and private sectors. Conducted as part of the Center's Affiliates program, the forum was one of a series which brings together small groups of executives from private and public organizations involved in transportation to examine how the economic and technological trends of the decade will impact the development of our transportation system.

Seminars. In addition to the forum, the Center's increased efforts in logistics and the summer subjects in transportation -- all of which are of benefit to the industry at large as well as the Center's corporate affiliates -- several efforts were mounted for the exclusive benefit of our affiliates, including seminars on the financial evaluation of motor carriers and on the effect of labor developments on transportation. A one-day meeting was also held at the main distribution facility of the United Parcel Service featuring on-site discussions of operational concepts by UPS representatives and MIT faculty.

TRANSPORTATION COMPUTATION LABORATORY

In keeping with the increasing use of computers in transportation, the Center established the Transportation Computation Laboratory in 1983, open to students and faculty 24 hours a day. The laboratory is designed to provide its users with all levels of computational power from the personal computer to the Institute's largest mainframes. A number of notable models have been developed in the laboratory during its brief operation, including a transit fare and route analysis model and a truckload routing and scheduling model. Future plans include the addition of interactive video systems and high-resolution graphics terminals.

GERARD J. MC CULLOUGH
The classroom education program of the Innovation Center is strong, with three graduate-level subjects being offered. These three subjects, Invention, Product Design, and Entrepreneurship, form a logical sequence spanning the multi-disciplinary spectrum of the technological innovation process. A number of students participate in all three subjects, indicating strong professional and career interests in innovation and entrepreneurship. Approximately 100 students participated in the various activities of the Center this year. The level of participation has been stable over the past few years. A number of students are presently involved in new venture start-ups, under the care and counsel of the Innovation Center.

The Industry/Innovation Center Cooperative Program continues to develop as the primary source of support for graduate research in the Innovation Center. Its focus is product creation and development to meet the market needs of member companies. Efforts continue to be made to expand this valuable educational opportunity.

Future development of the Innovation Center's educational program includes establishment of "internships" in new product development and new venture formation. These activities will be special projects, carried out by students under faculty supervision, involving the design and preparation for market of new products created by these students or laying the groundwork for a new enterprise. A small amount of financial resources will be available from the Center for this program.

DAVID G. JANSSON
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, library science and management. Since that time, the Laboratory's pursuits expanded, leading to pioneering research in 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 the problem domain. Examples are the use of expert medical knowledge for assistance in diagnosis carried out by the Clinical Decision Making Group; and the use of solid-state circuit design knowledge for an expert VLSI (very large scale integration) design system by the VLSI Design Project.

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. New research in this area includes architecture of very large multiprocessor machines (which tackle a single task, e.g., speech understanding or weather analysis) by the Computation Structures, Functional Languages and Architectures, and Real Time Systems Research Groups. Continuing research includes the analysis and synthesis of languages and operating systems for use in large geographically distributed systems by the Programming Methodology, and Real Time Systems Groups. Extended networks for such distributed environments are studied by the Computer Systems and Communications Group, while distributed file servers are pursued by the Distributed Computer Systems Group. Finally, a key application involving the matching of news and other community information to individual needs, is pursued by the Imaginative Systems 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, entails societal as well as technical aspects of the interrelationships between people and machines. Examples include the use of computers in the educational process by the Educational Computing Group; the use of interconnected computers for planning; as well as the societal impact of computers carried out by the Societal Implications Research Group.

During 1984-1985 the Laboratory continued its ambitious project of constructing a Multiprocessor Emulation Facility consisting of 64 interconnected Lisp Machines, whose purpose is to analyze the behavior of larger (up to several thousand machines) multiprocessor systems. This facility, funded by the newly formed Strategic Computing Program of the Defense Advanced Research Projects Agency, will enable our experimenters to try out ideas before committing their proposed architectures to silicon circuits. Another related development during this period has been the continued successful development of the MULTILISP language for multiprocessor systems by Professor Robert Halstead of the Real Time Systems Group. This language and the Emulation Facility will be used in the coming year to assess the effectiveness of multi-processors in carrying out a variety of new applications.

Another important growth activity has been the evolution of a research and development plan for the LCS Common System. Through this system, the Laboratory aspires to interconnect effectively, heterogeneous computer resources. Current distributed computer systems entail networked, generally identical computers which intercommunicate at the relatively low level of exchanging text and other computer files. The LCS Common System will deviate from this approach in two ways. First, it will admit dissimilar computers, such as Lisp Machines and Vaxes. Second, it will permit sharing data and procedures among these different environments so that our researchers may build on each other's work, as if they were using a single time shared computer. In addition, the system will enable access by every researcher of unique laboratory
resources such as the Multiprocessor Emulation Facility and the Expert VLSI Design System. We expect that implementation of this major project will begin January 1986 and will last for at least three years.

During 1984-1985 the Laboratory has continued its successful Distinguished Lecturer Series with presentations by Mr. Steven Jobs, Chairman of Apple Computer; Professor Roger Schank of Yale University; Professor Stephen Cook of the University of Toronto; Admiral Bobby Inman, President of MCC; Professor Carver Mead of the California Institute of Technology; and Mr. Kenneth Thompson, a co-developer of UNIX from AT&T Bell Laboratories. Also during the same period the Laboratory employed 24 undergraduates through the "Hacker Heaven" project which strives to identify promising potential researchers in computer science.

During 1985, the following members of the Laboratory were honored with awards: Professor David Gifford with the ITT Career Development Chair; Professor Charles Leiserson with the NSF Presidential Young Investigator Award; Professor Barbara Liskov as NEC Professor of Software Technology; and Professor Sherry Turkle as Ms. Magazine's Woman of the Year.

Other changes include the appointment of Dr. Karen Sollins as Head of Computer Resources, taking over from Dr. David Clark who will now lead the Laboratory's Common System research effort. Professor Jerome Saltzer, who heads the LCS Computer Systems and Communications Research Group, has been named Technical Director of Project Athena in the School of Engineering. Arrivals included Assistant Professors Rishiyura Nikhil and William Weihl and Visiting Scientist Richard Greenblatt. Departures during the same period were Research Associate Benjamin Kuipers of the Clinical Decision Making Group to the University of Texas, Mr. Albert Vezza, Head of the Programming Technology Group who became Chairman and Chief Executive Officer of Infocom Incorporated, Professor J.C.R. Licklider who is retiring, and Research Associates David Lebling and Christopher Reeve who have also gone to Infocom Incorporated.

Our Laboratory consisted of 352 members -- 42 faculty and academic research staff, 35 visitors and visiting faculty, 65 professional and support staff, 110 graduate and 100 undergraduate students -- organized into 16 research groups. Laboratory research during 1984-1985 was funded by 16 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.

Technical results of our research in 1984-1985 were disseminated through publications in the technical literature, through Technical Reports (TR318-TR330), and through Technical Memoranda (TM263-TM279).
Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 17 faculty and 10 research staff from the departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented include power electronics, automatic control, electromechanics, continuum electromechanics, heat transfer, insulation research, quantitative physiology, cell biology and economics. While fostering interdisciplinary interactions with other Institute and area laboratories, LEES is designed to encourage interdisciplinary activities.

POWER ELECTRONICS

Centering on the MIT-developed Parity Simulator and close interactions with industry, Professors J. G. Kassakian and M. F. Schlecht lead power semiconductor research programs to exploit developing capabilities (with the Microsystems Technology Laboratory) for the fabrication of integrated power semiconductors as well as wafer-like integrated inductors and transformers. The evolution of power circuit topologies demands an increasing emphasis on electromagnetic field analysis and thermal considerations.

After successfully demonstrating the practicality of dc/dc converters operating at switching frequencies in excess of 10MHz, the laboratory is aggressively engaged in developing the material, component and fabrication technology necessary to mass produce such power supplies. A new power mos field effect transistor has been designed with an integral turn-off device, permitting high switching efficiencies to be achieved at these frequencies.

The Power Electronics Collegium has grown to thirteen industrial members, and continues to be a source of support and guidance for the power electronics activities of the laboratory. Through the continued development of a graduate subject and a summer course, power electronics research has a strong influence on graduate and continuing education. The capability for interfacing computers and other digital electronic devices with electromechanical systems made possible by this activity is in strong support of other laboratory research projects.

AUTOMATIC CONTROL

Parameter estimation, especially in distributed systems, is an area of increasing emphasis in the laboratory. Professor J. H. Lang has shown theoretically and numerically that model reference adaptive identifiers previously developed for large space structure parameter identification, also work well for rotating machines. The results of this work are being applied to the superconducting generator program as a means of detecting superconducting operation. The same numerical experiments indicate promise for inexpensive predictive maintenance in common electrical machines.

By means of theory and numerical experiments, Professors J. H. Lang and G. C. Verghese have shown that state estimators driven by voltage and current measurements from the terminals of an electric machine can be used to estimate rotor position (or rotor and stator flux) with sufficient accuracy to replace shaft encoders (or support torque control in a wide range of applications) for the purposes of commutation and perhaps for fine position control.

Using methods of numerical linear algebra, Professor Verghese has been active in the development of algorithms for analysis of multiple-wavelength chromatographic data. Initial tests have shown great improvements over currently used methods. The algorithms hold promise of more fully exploiting the capabilities of modern computer-controlled chromatographic equipment and are now being developed commercially.

ELECTROMECHANICS AND HEAT-TRANSFER

The Integrated Machine is a continuing theme for research guided by Professors Lang, Verghese, and Thornton that draws upon the interdisciplinary strengths of the laboratory. Using an approach in which the interaction of power conditioning apparatus, control strategies and machine design are emphasized, Professor Lang has successfully completed a theoretical and experimental treatment of a 3.8-kW variable reluctance motor variable speed drive. This work has been projected to a 60-kW drive for electric vehicle propulsion with a mass of 65 kg and efficiency in excess of 95 percent and has led to industrially sponsored work on variable speed drives for pumps, fans and compressors and for servo-robotic type systems.

With the objective of a new technology for large synchronous generators, Professors G. L. Wilson, J. L. Smith Jr., J. L. Kirtley and Dr. S. D. Uman, Mr. D. M. Otten, and Mr. W. H. Hagman are constructing and testing a 10 MVA superconducting machine. The experimental machine is designed to test new mechanical...
electromechanical, insulation and thermal design concepts, including a field-winding support scheme which isolates the superconducting winding from transient forces, a two-component rotor electrical shielding system and a novel cryogenic rotor cooling system. The machine is nearing completion and has passed a number of major milestones. A recent achievement indicating that complex mechanical-thermal design and construction requirements can be met has been the cooling of the rotor to liquid helium temperatures and the observation of a superconducting state for the field winding.

A second milestone that has now been achieved is the successful surge testing of the armature. This winding demonstrates new features that are expected to be useful in various turbine-generator systems, including a limited voltage gradient winding scheme, a helical winding form, the use of an electrically insulating structure with filament-wound glass fibers and epoxy adhesive and a cooling fluid that doubles as an insulating impregnant. After an unsuccessful industrial attempt, this armature was fabricated in LEES.

These research activities undergird the development of subjects and teaching aids relating to rotating machines. In connection with the 4th addition of Electric Machinery, (McGraw-Hill, 1983) co-authored with Professor Kingsley and the late Professor Fitzgerald, Dr. Umans has authored the educational computer software "Electric Machinery Software". Professors Lang and Verghese have brought their research interests into the classroom through the development of a subject interfacing the computer with physical systems using modern concepts of automatic control.

CONTINUUM ELECTROMECHANICS

Whether directed toward physiological research or air pollution control, the laboratory has a continuing interest in the mechanics and electromechanics of multiphase media. Professor M. Zahn has completed work to show that electric polarization forces can be used to electrically stabilize gas fluidized beds in a manner analogous to that achieved magnetically elsewhere. Professor J. R. Melcher has completed two related studies, each requiring an understanding of the propagation of low frequency acoustic energy through oil-filled underground conduits used for high voltage transmission. These projects were concerned with the protection of substation equipment from fault generated pressure surges and with the detection of leaks.

Of continuing interest to Professor Melcher are processes involving electrically induced migration of charged macroscopic or microscopic particles through turbulent media. Work aimed at the development of an ac electrostatic precipitator for the control of the highly insulating products from combusting western coals has resulted in laser-doppler velocimeter documentation of processes occurring when macroscopic particles are simultaneously charged and precipitated in a turbulent flow. Results of this work include a model for predicting efficiency of single stage ac precipitators (in which ion migration times are short compared to the period of excitation) and a new technique for measuring the longitudinal turbulent diffusion coefficient.

Under the supervision of Professors Melcher and Zahn, work has been completed using controlled experiments correlated with theoretical models to elucidate processes at work when insulation failure occurs as a result of pumping highly insulating coolants (such as Freons) through insulating conduits. This effort relates to a long term interest in understanding electrokinetic processes in highly insulating liquids where double-layers are forced out of equilibrium by external fields and flows that may be laminar or turbulent. A new flow meter has been developed which non-invasively senses the fluid velocity or the streaming current and which promises, through the use of microfabrication, to make possible the probing of the Debye layer. A new project stemming from this work is concerned with insulation failures that have been observed in transformers. Here, the adsorption of additives on liquid-solid interfaces, found to be an important part of the electrokinetic processes, will be correlated with electrophysiological experiments using results of the micro-chip part of the transformer program to be described.

HIGH VOLTAGE AND INSULATION RESEARCH

In his work with high Kerr constant liquids, Professor M. Zahn has shown that with bipolar charge injection, achieved by selection of appropriate electrode materials, the charge decreases the electric field at both electrodes and thereby allows up to a 40% higher voltage breakdown strength. These results have changed previous thinking that the highest breakdown strength occurs with no charge injection. The success of these measurements has led to reconsideration of designs for pulsed power machines.

Professor Zahn has extended his electro-optical approach to the non-invasive measurement of field and charge distributions and of ion migration phenomena in liquid and solid insulation so that measurements can be made on weakly birefringent materials. The new computer based system, which makes use of an optical multichannel analyzer, provides for rapid quantification and processing of data. This has made possible a new major program (through the auspices of the MIT Electric Utilities Program) aimed at understanding charge injection processes in liquid and solid insulation used in power systems apparatus.
Dr. C. M. Cooke completed work on the reliability of compressed gas apparatus. This study was coordinated internationally through CIGRE, where Dr. Cooke is a US Expert Representative and secretary to the Working Group on Gas Insulation.

Dr. Cooke coordinates a three year program, initiated this year, to develop practical monitoring techniques and methodologies to determine and predict hazardous conditions within large transformers before they fail. Through the auspices of the MIT Electric Utility Program (Energy Laboratory) this project brings together efforts to exploit recently developed semiconductor microchip technologies (Laboratory for Material Science) for sensing transformer oil constituents (Professor J. R. Melcher), electromechanical vibration analysis (Professor J. L. Kirtley Jr.), fast pulse counting methods (Dr. C. W. Cooke), trend analysis and database management techniques (Professor F. C. Schweppe and Dr. R. D. Tabors). A general technique has been evolved for modeling heterogeneities, such as introduced by physical adsorption at interfaces, that make the microdielectrometer "chip" applicable to a range of sensing needs.

**Quantitative Physiology, Cell Biology and Radio Therapy**

Interactions between electromagnetic fields and physiological systems are being studied at the tissue and cellular levels in work that draws upon the laboratory's expertise in continuum mechanics and electromechanics. Professor A. J. Grodzinsky is studying the balance between degeneration and repair in cartilage associated with osteoarthritis. It has been found that electric currents applied to cartilage are transduced into mechanical deformations and loads within the tissue. Ongoing research in chemical and electrical control of polyelectrolyte membrane transport and hydration has potential applications in drug delivery, separations and micromanipulators. Recent results show that 20-100 fold changes in transmembrane flux are induced by controlled changes in intramembrane pH. Furthermore, applied mechanical loads appear to affect cellular behavior in living cartilage tested in organ culture.

This latter finding is supported by the work of Professor R. C. Lee, whose activities focus on elucidating the mechanisms through which electrical and mechanical forces regulate cellular growth and metabolism. During recent months, he has gained insight into the kinetics of the cellular response to electric fields by measuring the frequency bandwidth of electrochemical processes, providing a quantification of changes in protein biosynthesis. Other findings are that the response of cells to electric fields is dependent on the extracellular matrix structure and that static mechanical stresses can not only induce cellular alignment but that collagen in developing tissues can be aligned as well. This latter result facilitates Lee's efforts to produce ligament substitutes, an application motivated by his clinical practice.

Supported by evidence gathered from published research suggesting that electric fields may damage cells by non-thermal mechanisms, Professor Lee has supervised work suggesting non-thermal toxic effects on human fibroblasts in tissue culture. This work, which has resulted in a research program sponsored by the electric utilities on the physical mechanisms for cellular destruction in electrical injuries, is aimed at improved clinical approaches to the treatment of electrical burns.

After many years of service as an adjunct to the radiotherapy facilities of the Lahey Clinic, the low megavolt electron beam therapy service of the high voltage laboratory has been transferred to the Lahey Clinic. This has been made possible by Mr. K. A. Wright, who has been responsible for putting into operation the Lahey facility for the treatment of local and extensive skin malignancies. Mr. Wright continues to be active in simulation radiotherapy work, most recently developing intra-oral cones for 5-12 MeV electron beam therapy and serving on committees for the American Association of Physicists in Medicine and the National Cancer Institute.

**Power Systems Integration and Economics**

The Integrated Energy Systems Project is currently carried out jointly with Dr. R. D. Tabors and five international partners to address energy technology development for the next two decades. During the past year specific research activities include studies (by Professor M. El-Maazil) of high efficiency gas turbine combined cycle systems, in development of biomass based technologies for liquid fuels and in the development of tightly linked chemical, electrical and thermal systems. Studies have also been completed using the MIT developed Electric Generation Expansion Analysis System (EGEAS) to evaluate the potential for conventional Natural Gas fired combined cycle systems in U.S. Utilities.

The concepts of "spot pricing", developed by Professor F. C. Schweppe and Dr. Tabors takes advantage of the revolution in communication and computational technologies to allow for a significant evolution toward real time pricing of electricity for both large industrial and specific residential customers. During this past year, work in this area has been extended by Professor Schweppe to pricing power "wheeled" between utilities. Following on their own research and development activities, Professor Schweppe and Dr. Tabors taught, for the second year, a special summer session "Power System Planning and Operation: Methodologies for Dealing with an Uncertain Future", attended by representatives of the utility industry, large consumers, and utility regulators.

JAMES R. MELCHER
Laboratory for Information and Decision Systems

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 Director of the laboratory is Sanjoy K. Mitter, Professor of Electrical Engineering. Robert G. Gallager, Professor of Electrical Engineering, is the Associate Director. The Assistant Director is Stanley B. Gershwin, Principal Research Scientist.

Thirteen faculty members and seven research staff members are presently associated with the laboratory. In addition, approximately sixty graduate students conduct research in LIDS. Currently, the laboratory provides thirty-five research assistantships to graduate students. A number of undergraduate students also participate in research and thesis activities.

Financial support for research in the laboratory is provided by Defense Advanced Research Projects Agency, Army Research Office, Office of Naval Research, Air Force Office of Scientific Research, National Aeronautics and Space Administration, National Science Foundation, National Institute of Health, IBM Corporation, Dupont Corporation, General Electrical Company, Data General Corporation, Codex Corporation, Motorola, Inc., and the Analytical Sciences Corporation.

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.

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 band 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 filters and heterodyne detection to achieve dynamic frequency concurrency. Professors Robert Kennedy and Pierre Humblet are conducting the research.
Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis, and signal processing problems are being studied by Professors Bernard C. Levy, Sanjoy K. Mitter, John Tsitsiklis, George C. Verghese, and Alan S. 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 the 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 Professors Michael Athans, H. Austin Spang III, Gunter Stein, and Dr. Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of VTOL aircraft, submarine control systems, 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. Professors Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

Command, Control, and Communication Systems

The study of military Command, Communication, and Control (C3) systems defines basic research directions in the areas of distributed detection and estimation, distributed data bases, and team decision theory. Professors Michael Athans, Dr. Robert R. Tenney, 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; (c) multisensor-multobject tracking algorithms including sensor scheduling; (d) integration of distributed data base systems within vulnerable communication networks; (e) development of a computer-based testbed in support of analytical research.
Manufacturing Systems

Modeling, analysis, and control of manufacturing systems are studied by Dr. Stanley B. Gershwin, Professor Sanjoy K. Mitter, Dr. Ramakrishna Akella, 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. The FlexMan computer system was developed by Ms. Elizabeth R. Ducot to help transfer our results to industrial users.

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.

Three current projects include analytical and experimental investigations of: (1) electronic document-delivery networks applicable to interlibrary resource-sharing; (2) expert computerized intermediary systems to assist end-users in accessing and operating heterogenous bibliographic databases and retrieval systems; and (3) intelligent terminals with microprocessor and telecommunications hardware and software that enable automatic connection and log-in to remote computers. Staff members directing these three efforts are, respectively, Professor J. Francis Reintjes, Mr. Richard S. Marcus, and Mr. John E. Ward.

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 also is concerned with probability assessment, particularly the quantification of expert judgement.

New Appointments

Professor John Tsitsiklis has joined the laboratory effective September 1, 1984. He is an Assistant Professor in the Department of Electrical Engineering and Computer Science.
The Long Range Goal of The Laboratory for Manufacturing and Productivity (LMP) continues to be the establishment of a scientific discipline for the field of manufacturing. The Laboratory's efforts toward achieving this goal are expressed in both its teaching and research activities. In the course of the year, a wealth of students has passed through the Laboratory and has been educated to address issues related to all aspects of manufacturing by using rigorously developed scientific methodology. A wide variety of new subjects has been developed by the faculty and staff of the Laboratory. The new subjects include the Design and Analysis of Robotic Manipulators, Theory and Practice of Machine Tools, Manufacturing Processing Systems, etc. On the research side, the Laboratory's faculty and staff continue their efforts toward solving problems in the area of manufacturing using innovative approaches.

The Laboratory is almost 150 people strong and has more than $3 million in research support, primarily from industry. This industrial support exceeds the support from government agencies by nearly a factor of three, and, although our faculty and staff address a variety of research problems encountered in the manufacturing industry, the nature of the basic academic research has not been compromised. Indeed, as a result of the efforts of the Laboratory's faculty and staff, basic principles for manufacturing have been developed and, very often, applied in solving industrial problems.

During the academic year 1984-85, the Laboratory underwent some major personnel changes, the first being the resignation of our Director, Professor Nam P. Suh. Professor Suh, a world-renowned leader in the field of manufacturing, has been appointed Assistant Director for Engineering at the National Science Foundation and has, therefore, left the Laboratory. In addition, Professor Suh resigned from his position as the Director of the MIT Industry Polymer Processing Program. The program, with a new emphasis on research of new composite materials, is now directed by Professor Tim Gutowski.

During the past academic year, the Laboratory started numerous new research activities while continuing to work on already existing projects. Issues related to manufacturing systems have become a major focal point of the Laboratory's research activities. A major project given by CAM-i, related to decision making techniques and artificial intelligence technology applications for the operation of manufacturing systems, has been one of the new areas of the Laboratory's activities. Professor Suh's work in the axiomatic approach to manufacturing has continued, and several new research projects for industrial application of this novel concept for the integration of manufacturing and design are being applied to industrial problems. Professor David Hardt's work in forming and welding processes and their intelligent control has brought further attention of the scientific and industrial community. The Tribology Research Program, directed by Professor Ernest Rabinowicz and Dr. Nannagi Saka has undertaken a number of industrial projects during the past year which parallels the program's basic research in the fundamental mechanisms of friction, lubrication, and wear. The rapid growth of the Tribology Research Program in recent years can partially be contributed to the emphasis of the program on tribological issues of electronic equipment. The Laboratory continues to undertake research through cooperative research programs with industry because cooperative research provides a convenient and effective vehicle for coherent long-term basic research which, by the same token, addresses industrial manufacturing problems.
The Materials Processing Center (MPC), formed within the Massachusetts Institute of Technology's (MIT) School of Engineering in 1980, aids 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 $5 million. NASA still provides about 20 percent of the MPC's total budget, with 40 percent provided directly by industry, and another 40 percent from other governmental agencies.

Dr. R.M. Latanision, Shell Distinguished Professor of Materials Science and Engineering, became the new director of the MPC in December, 1984. Professor Latanision, recognized internationally for his work introducing the fundamental principles of materials science into corrosion engineering, also directs the H.H. Uhlig Corrosion Laboratory. He succeeds Dr. H. Kent Bowen, Ford Professor of Engineering, who left the MPC in August 1984 to become the director of the new Manufacturing Systems Program.

INTERDISCIPLINARY, FUNDAMENTAL RESEARCH

The MPC's basic philosophy revolves around learning how to regulate a material's performance by controlling its internal structure, from the macroscopic to the microscopic. This control must be based on a fundamental understanding of the basic science of materials processing rather than on a purely empirical view; that is, to understand how and why a process successfully controls microstructure and subsequent properties rather than simply that it works. The MPC also strives to increase the number of materials processing students and professionals, 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 economical control of structure, properties, and performance. In addition, projects have both practical and fundamental significance, with many related to space processing. Many researchers in both ground-based and reduced gravity environment-based studies are increasing their use of mathematical modeling techniques as a research tool. The interdisciplinary nature of many projects requires the involvement of a number of faculty, staff, and students from several different departments, including Chemical Engineering, Civil Engineering, Nuclear Engineering, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemistry.

The Metal Matrix Composites Processing Laboratory (MMCPL) has grown rapidly since its inception in 1984, more than doubling its research budget. In April, the Office of Naval Research awarded a $1.5 million grant to the MMCPL to investigate the fabrication, testing, and analysis of metal, ceramic, and fiber-reinforced composite materials. Research will include studies of (1) strong, lightweight composite materials for large space structures, (2) materials with high dimensional stability including the ability to withstand the stresses caused by rapid cycles of expansion and contraction, and (3) special composite materials for resistance to radiation in space.

COLLABORATION WITH INDUSTRY

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 Materials Processing Center has encouraged a close relationship with industry through its Industrial Advisory Board, Industry Collegium, and research consortia. The Board, whose members all come from industry and government, annually reviews the ongoing research programs and policies of the MPC, promoting direct interaction with industry. The Collegium, now with 51 worldwide corporate member companies, encourages close contact between industrial representatives and MPC personnel through workshops, visits, and tours of the research facilities. Person-to-person contact between visiting scientists from these companies and our faculty, staff, and students encourages the flow of creative ideas in both directions, while providing excellent opportunities for bilateral information and technology exchange.
The consortia, or multi-client sponsored research concept, was adopted in 1980 to promote collaborative, generic materials processing research. Three such consortia now exist in the Center, the Materials Systems Analysis Consortium, the Welding Consortium, and the Ceramic Powder Processing Research Consortium (CPPRC). The Materials Systems Analysis Consortium, established last year, now includes 20 companies and continues to grow rapidly. It helps companies to take a comprehensive view of strategy planning to account for the economic, political, and technical interrelationships between materials. The CPPRC, the largest of the three consortia, now has an annual research budget of $1 million contributed by its 30 members from industry and government. Research funded by the consortium studies fundamental, generic processing concepts, which each participating company can then adapt to its own proprietary technology. It is through groups such as these that the MPC strengthens the link between basic research at the university and innovation in industry.

The MPC undertakes educational and advisory roles in addition to its research role. Through the Collegium, the MPC sponsors informative workshops, graduate fellowships, and summer scholarships. The major benefits of the workshops, which have been well attended by industrial, university, and government personnel, are the timely dissemination of research results and the ensuing exchanges between speakers, Center staff, and attending industrial representatives. Workshops held last year dealt with "Rapid Solidification Processing," "Quantitative Assessment of Materials Markets," and "Processing, Structure, Properties, and Performance of Metal Matrix Composites." Workshops planned for next year will cover ceramic powder processing, mathematical and physical modeling, polymer composite processing, and thin film electronic materials.

The fellowship program, established in 1982, endeavors to attract the very best entering graduate students to materials processing. For the 85/86 year, the MPC has offered 22 fellowships to students in the Departments of Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemical Engineering. The many departments involved in this program illustrate the interdisciplinary components of materials processing research and development. Similarly, the summer scholarship program, also begun in 1982, seeks to encourage undergraduate students to pursue an education and career in materials processing at MIT. For the summer of 1983, the MPC has offered eight summer scholarships to sophomores and juniors enrolled in chemistry, physics, and mechanical, chemical, and electrical engineering 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 autumn to complete their undergraduate programs.

Collegium member companies also receive Collegium Reports, which provide timely access to research reports. In addition, the MPC encourages representatives from these companies to tour Center facilities, or to send representatives for an extended visit during which they participate in current research projects. With Collegium funds, the MPC develops new curriculum and texts, aids in the purchase of necessary major equipment, and supports seed research projects. The MPC also offers an intensive two-week summer course on Applied Materials Technology for industrial representatives as well as special groups such as NASA's astronauts.

LINKS WITH GOVERNMENT

In addition to its ties with NASA, the MPC encourages interactions with other governmental agencies. This past year, the MPC staff has been working with the Massachusetts Technology Park Corporation (MTPC) to develop an aggressive development plan for advanced materials research, characterization, and applications. There has been a policy void in the United States at both the state and national level concerning the development of new materials, materials processes, and new products which would reduce manufacturing costs, energy consumption, and natural resource depletion and which would improve productivity. For the US to remain competitive in world markets, this policy void must be filled. In response to this challenge, the Director and Associate Director of the MPC have worked with an ad hoc committee of the Commonwealth's industrial and academic leaders to develop a preliminary program plan for the establishment of the Massachusetts Advanced Materials Characterization and Applications Center (MAMCAC). This center, a sibling to the Massachusetts Microelectronics Center under the umbrella organization of the MTPC, will centralize all the necessary characterization instrumentation that researchers at various universities and industry require to develop new materials and products. The development plan has received initial approval by the MTPC and is now awaiting final action by Governor Dukakis.

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 five 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, American industry can retain and maintain its leadership in basic processing, the keystone of high technology and advanced materials systems.

R.M. LATANISION
School of Humanities and Social Science

This year has seen a number of new initiatives in the School of Humanities and Social Science with respect to undergraduate and graduate education.

The initiatives connected to undergraduate education are aimed at strengthening the role and content of the humanities and social sciences in the MIT curriculum and have two distinct but related foci: (1) to develop an integrative core curriculum that would provide more cohesion and structure to the existing HASS requirements while serving to make the humanities and social sciences play a more meaningful role in the education of future scientists and engineers; and (2) to develop a program in the liberal arts that would build upon MIT's strength in science and technology and provide a liberal education that would serve to link the humanistic and scientific cultures. To this end, a number of discussions between the Engineering and SHSS Councils were held during the past year, culminating in a two-day meeting held in early May in Woodstock, Vermont. As a background to this meeting, two committees with memberships from the Schools of Engineering, Science, and Humanities and Social Science were established: one, chaired by Professor Travis Merritt, discussed the history of the humanities and social sciences at MIT and outlined efforts to integrate a liberal and a technical education at the Institute; the second, chaired by Professor Kenneth Keniston, discussed the MIT environment and possible structures for a revised HASS curriculum.

To follow up on these reports and meetings, two new committees have been established. One, chaired by Professor Pauline Maier, will develop a proposal for a restructured HASS requirement; the other, chaired by Professor Leo Marx, will develop a proposal for an undergraduate program that will serve to integrate a liberal and a technical/scientific education. Because of the Institute-wide educational implications of these initiatives, each committee has membership from the other Schools. In addition, the HASS Committee is jointly sponsored by the Offices of the Dean for Undergraduate Education and the School of Humanities & Social Science.

During the winter, a graduate committee, chaired by Professor Myron Weiner, was established. This committee is charged to review graduate programs in the School to see if potential linkages and connections are being exploited as fully as possible; to evaluate proposals for possible new graduate initiatives; to examine the problem of graduate student support; and to examine problems dealing with research funding and faculty support.

The enrollments in the School are indicative of the range of foci within its Departments. The four graduate departments (Economics, Political Science, Linguistics and Philosophy, and Psychology) continue to have large graduate enrollments, which are primarily concentrated in doctoral programs. These Departments are distinguished, attract able and energetic graduate students, and, with the exception of Economics, play a relatively modest role in the Institute's undergraduate program.

In terms of undergraduate education, the departments and sections within the School are notable for the relatively small number of students who major in their disciplines in spite of efforts to develop programs that would attract undergraduates. In this regard, the Psychology Department has experienced some success in developing its new major in cognitive science. Although the small number of majors does not present a significant problem for the departments with graduate programs, it creates a situation in which the faculty of the sections and programs in the rest of the School are limited to teaching undergraduates under the aegis of the Institute-wide HASS requirements - primarily the Hum-D and the concentration requirements. Since students who take these required subjects typically have a primary interest elsewhere, they often lack a real commitment to the subject matter, which is a source of some frustration for many of the faculty within the School. Indeed, attracting a group of students with a more fundamental interest in the humanistic disciplines would have a strong positive effect upon the School, and the curriculum changes will be designed with this goal in mind.

Members of the faculty within the School received a number of notable honors and awards over the past year. Professor Albert R. Gurney of the Literature faculty was elected to the Council of the Dramatists' Guild, while Professor Merritt Roe Smith was appointed as Regent's Fellow to the Smithsonian Institute. Professor Richard Held, Head of the Psychology Department, received the Kenneth Craik Award from St. Johns College, Cambridge University, while Professor Wayne O'Neill was appointed Honorary Professor of Linguistics in Shandung University, Peoples Republic of China. Professor Kenneth Manning, Head of the Writing Program and a member of the STS faculty, received the Pfizer Award of the History of Science Society for his book, Black Apollo of Science. Professor Charles Kindleberger and Professor Evsey Domar, both Emeriti of the Economics Department, respectively served as President and Distinguished Fellow of the American Economic Association. For the coming year, Professor Susanne Berger of the Political Science Department will serve as the holder of the French-American Foundation chair in American Civilization. Professor Daniel McFadden of Economics is currently serving as President of the Econometric Society.
A number of important personnel changes took place this year. Professor Cynthia Wolff of the Literature Faculty became the first Class of 1922 Professor in the Humanities, while Dean Burnham and Suzanne Berger respectively became Sloan Professor and Ford International Professor of Political Science. Institute Professor Paul A. Samuelson retired from the Economics Department after providing intellectual leadership to it and to the profession for many years. Professor Samuel J. Keyser stepped down as Head of the Linguistics and Philosophy Department after eight years to assume a new position as Associate Provost for Educational Policy and Planning. He will be succeeded by Professor Richard L. Cartwright. Professor Mary Potter of Psychology will be Chairman of the Faculty for the next two years. Professor E. Cary Brown assumed the role of Acting Head of the Department of Economics upon my appointment as Dean of the School of Humanities and Social Science. Professor Brown will serve as Associate Dean and Head of Foreign Languages & Literatures during the coming year, while Professor Peter Diamond will become Head of the Economics Department. Finally, Harold J. Hanham stepped down as Dean of the School of Humanities and Social Science, after a term of 11 years that is notable for the strengthening of the School within the Institute. He leaves a legacy that will be hard to follow.

During this year, the Women's Studies Program assumed its first year of formal operation, and the Humanities Undergraduate Office continued to coordinate the Humanities majors, the Hum-D offerings, and the concentrations within the School. The reports of the Humanities Undergraduate Office and the Women's Studies Program follow this report.

ANN F. FRIEDLAENDER
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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.
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<td>(40) 37</td>
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<td>( 2) 1</td>
<td>( 6) 5</td>
<td>( 12) 6</td>
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<tr>
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<td>(42) 3</td>
<td>(64) 57</td>
<td>(124) 61</td>
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<tr>
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<td>(745) 173</td>
<td>(1043) 992</td>
<td>(2226)1200</td>
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* 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:

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<tr>
<th>Languages</th>
<th>Class of 1988</th>
<th>Class of 1987</th>
<th>Class of 1986</th>
<th>Class of 1985</th>
<th>Totals in Fields</th>
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<td>French</td>
<td>(3) 1</td>
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<td>(58) 52</td>
<td>(147) 85</td>
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<td>German</td>
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<td>(45) 16</td>
<td>(33) 38</td>
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<td>(19) 3</td>
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<td>(26) 6</td>
<td>(23) 22</td>
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### TABLE III

Undergraduate Majors in the School of Humanities and Social Science*

<table>
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<tr>
<th>Year</th>
<th>Economics</th>
<th>Humanities**</th>
<th>Philosophy</th>
<th>Political Science</th>
<th>Psychology***</th>
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<td>48</td>
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<td>1976-77</td>
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<td>31</td>
<td>7</td>
<td>25</td>
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<tr>
<td>1977-78</td>
<td>52</td>
<td>34</td>
<td>7</td>
<td>21</td>
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<td>114</td>
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<tr>
<td>1978-79</td>
<td>48</td>
<td>38</td>
<td>5</td>
<td>30</td>
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<td>1979-80</td>
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<td>126</td>
</tr>
<tr>
<td>1980-81</td>
<td>50</td>
<td>40</td>
<td>11</td>
<td>30</td>
<td>--</td>
<td>131</td>
</tr>
<tr>
<td>1981-82</td>
<td>51</td>
<td>49</td>
<td>9</td>
<td>32</td>
<td>--</td>
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<td>1982-83</td>
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<td>22</td>
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<td>117</td>
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<td>1984-85</td>
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<td>2</td>
<td>15</td>
<td>27</td>
<td>126</td>
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* As registered in the second term of academic year 1974-75 to 1984-85. 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.

*** Undergraduate degree in Cognitive Science, instituted in 1982-83.

### 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>Psychology</th>
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<td>95</td>
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<td>1975-76</td>
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<td>27</td>
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<td>1976-77</td>
<td>114</td>
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<tr>
<td>1981-82</td>
<td>111</td>
<td>55</td>
<td>142</td>
<td>26</td>
<td>334</td>
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<tr>
<td>1982-83</td>
<td>136</td>
<td>51</td>
<td>163</td>
<td>27</td>
<td>377</td>
</tr>
<tr>
<td>1983-84</td>
<td>113</td>
<td>52</td>
<td>99</td>
<td>25</td>
<td>289</td>
</tr>
<tr>
<td>1984-85</td>
<td>108</td>
<td>53</td>
<td>121</td>
<td>30</td>
<td>312</td>
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</table>

* As registered in the second term of academic year 1974-75 to 1984-85 (including special graduate students). Data taken from the Registrar's fifth-week report.
At the close of its third year, the Humanities Undergraduate Office is able to report a number of significant new accomplishments as well as a smooth continuation of its established functions. The workings of the office in 1984-85 benefitted from the staffing continuity we have enjoyed since February 1984. Travis Merritt continues as Director, Ruth Spear as Coordinator, Shawn Finnegan as Administrative Assistant, and Martha Lyman '88 was extremely helpful as student assistant.

HUMANITIES, ARTS, AND SOCIAL SCIENCES INFORMATION CENTER

The Humanities, Arts, and Social Sciences (HASS) Information Center continued to provide the various services to MIT students, faculty and administration enumerated in the Annual Reports for 1982-83 and 1983-84. The MIT Student's Guide to the Humanities, Arts, and Social Sciences went through two more editions, the Fall 1985 issue replacing the original tabloid with a more readable and manageable booklet format and a streamlining of content.

HASS Enrollment Statistics by Field and Subject

The Center completed its tabulation of subject-by-subject enrollment figures for all fields under the HASS Requirement from Fall 1979 to the present. These listings provide comparative sub-totals for HUM-D and Elective subjects, give enrollment levels for both Add Date and end-of-term, and indicate the number of sections for multi-section subjects. They also provide a complete record of subject number and title changes through the years. This compilation will be up-dated each term and the statistics are accompanied by several summary sheets and graphs. This Spring these statistics provided information for the two committees appointed by the Deans of Engineering and Humanities and Social Sciences to study the HASS Requirement.

HASS Concentration Statistics, Procedures, and Level of Compliance

For the second year, the Center kept a record of the populations in the 25 fields of HASS Concentration, counting both Proposals and Completions. This year, as last, Economics and Foreign Languages and Literatures are the most popular Concentration fields by a substantial margin, with Literature moving up to third in 1984-85.

It is worth noting that, despite two years of concerted effort, we are still a long way from achieving even majority compliance with the rule that students declare their fields of Concentration and fill out Proposal forms before the end of their Sophomore year. The total number of Sophomores with declared Concentrations climbed modestly from 355 in June 1984 to 418 in June 1985. To aid this compliance, the traditional Humanities Department Open House was expanded to an all afternoon event with accent on concentrations and included all HASS fields.

COURSE XXI

In addition to the administration of the full (XXI) and joint (XXI-E, XXI-S) major programs several other projects saw their completion during the year. The Course XXI Survey and Register, 1958-83 which covers the program's first 25 graduating classes was published and distributed in December. In conjunction with members of the Writing Program extensive work was done on the degree specifications in the area of scientific and technical writing. The Course XXI Policy Committee approved the first term of thesis work to be designated as a Pre-Thesis Tutorial (21 THT) and the second as the thesis (21 TH) itself, with a separate letter grade given for each term. A parallel arrangement applies to the General Examination in Music.

Students: Numbers and Quality

The total number of students enrolled in Course XXI, XXI-E, and XXI-S rose to 79 in May 1985, the highest level since the academic year 1972-73. The largest increase, this year as last, came in the full major program (XXI), which climbed from 28 to 34 students; there was a welcome gain in XXI-S (from 12 to 16), while XXI-E remained about stable. There was little change in the relative popularity of the several humanities fields; Writing, Literature, and Foreign Languages and Literatures among them account for more than half the population.

Last year we noted that, for the first time, more than half of our majors were also candidates for at least one other degree. In the May 1985 count, that phenomenon has waned: 32 of our students (39%) are double majors.
The generally high level of academic performance attained by XXIers during the past couple of years (and celebrated in comparative terms in last year's annual report) has continued in 1984-85.

Degrees, Honors, and Post-Graduation Plans

Two students received the S.B. in September 1984 (1 in XXI and 1 in XXI-E). Three students received the S.B. in February 1985 (2 in XXI and 1 in XXI-S) and 20 in June (4 in XXI, 11 in XXI-E, 5 in XXI-S), a total of 25 for the academic year.

XXIers in leadership positions during 1984-85 included: Inge Gedo '85 (German and Biology), elected Permanent President of her graduating class; Diana ben-Aaron '85 (Writing and Materials Science), Editor-in-Chief, The Tech; Anna Lisa Fear '86 (STS and Literature), President of Dramashop; William Maimone '85 (Writing and Computer Science), Chairman of the Interfraternity Council.

Prizes, honors, and awards: David Karohl '85 (German and Chemical Engineering) was elected to Phi Beta Kappa; Inge Gedo '85 won the Laya B. Wiesner Award, Eleanor Feingold '85 (Writing and Mathematics) took the Dewitt-Wallace Prize for Scientific Writing for the Public; Andrew Borthwick-Leeslie '87 (Literature) received the McDermott Prize for Playwriting; Terry Simpkins '87 (Literature and Biology) was awarded first prize for fiction in the Boit Writing Competition, and Dan Turner '87 (Writing and Film) second prize in the same competition; Diana ben-Aaron '85, Inge Gedo '85, William Maimone '85, and Anna Lisa Fear '86 earned listings in Who's Who among American College Students; Barrett Caldwell '85 (Social Psychology and Writing) received a National Science Foundation Fellowship for graduate study.

Some of this year's graduating seniors are moving on to graduate studies in, for example, chemistry at the University of North Carolina, public policy at the University of Michigan, psychology at UC Davis, computer science at MIT, and orthopaedic biomechanics at Stanford. Prospects for immediate employment include Sun Microsystems, Inc., Digital Electronics Corporation, Harvard University's admissions office, the Impulse Dance Company, Massachusetts General Hospital, Pacific Gas and Electric, the Navy, and the Air Force.

TRAVIS MERRITT
The year began with the appointment of Professor Ann F. Friedlaender, who had been serving so effectively as Department Head, as Dean of the School of Humanities and Social Science. Professor E. Cary Brown returned as Acting Head for the year to provide the Department sufficient time to choose her replacement. Professor Peter A. Diamond will become the new Head on July 1, 1985.

Several other important changes in personnel took place this year. We are pleased to report that Oliver D. Hart, a distinguished Visiting Professor this year from the London School of Economics, has elected to remain at MIT, and that Olivier J. Blanchard was promoted to Professor and Jean Tirole to Associate Professor with tenure. We regret to have lost Professor Eric S. Maskin who resigned to accept a position at Harvard University at midyear and Associate Professor Timothy J. Kehoe who elected to remain at Churchill College, Cambridge University. New Assistant Professors appointed for next year are Robert S. Gibbons who is completing his graduate work at the Stanford University Graduate School of Business, and Danny Ouah whose graduate work was at Harvard University.

Visiting faculty included: Professor Hart for the whole year; Visiting Professor Jean-Michel Grandmont of CEPREMAP, Paris, France; Visiting Associate Professor Halbert L. White of the University of California, San Diego; and Visiting Assistant Professor Drew D. Fudenberg of the University of California, Berkeley, in the fall term; Visiting Professor Frank H. Hahn of Churchill College, Cambridge University, in the spring term. Professor Bengt Holmstrom of the Yale School of Management and Social Policy was the Distinguished Lecturer this year during IAP, presenting a series of lectures on new work in labor-market incentives.

It is hard to believe that Institute Professor Paul A. Samuelson reached compulsory-retirement age this year, but we look forward happily to his continued active participation in research and other Departmental activities. One cannot overstate his contribution to the Department, MIT, and the profession in his remarkable career. He has been a major force in clarifying, consolidating, and formalizing economic theory in this century, and a renowned expositor of economics through his legendary textbook, now in its 13th edition. Honors have rightly been lavished on him. Of even more importance to those of us who have worked with him closely over the years has been his generous support in dealing with professional, academic, or personal problems. He has been the supreme colleague; the core of the Department. It is with no little trepidation that we try to close partially the massive gap that his retirement will create.

With great sadness the death of Emeritus Professor Paul N. Rosenstein-Rodan is reported. He came to MIT when the Center for International Studies was established under Max F. Millikan in 1952. After a distinguished career in the field of economic development as analyst and policy adviser, he began a whole new career that embraced another decade and a half as the creator and leader of the Center for Latin American Studies at Boston University. He was a wise and subtle colleague whose advice will be greatly missed.

Research has proceeded on many fronts, too diverse to summarize readily. Special mention should be made, however, of four major works: Professor Diamond's Wicksell Lectures have been published as A Search Equilibrium Approach to the Micro Foundations of Macroeconomics, Professor Paul R. Krugman's (jointly authored with Elhanan Helpman) Market Structures and Foreign Trade, Associate Professor Tirole's Concurrence Imparfaite, and Professor Martin L. Weitzman's popularly received The Share Economy.

Charles P. Kindleberger and Ezra N. Domar, Ford Professors Emeritus of International Economics, were honored: the first is serving this year as President of the American Economic Association; the latter was made a Distinguished Fellow of the Association at its meetings last December. Institute Professor Samuelson was the Horowitz Lecturer in Israel and received an honorary degree from the New University of Lisbon; Institute Professor Robert M. Solow was the Mitsui Lecturer at the University of Birmingham; Rudiger Dornbusch, Ford Professor of International Economics, was the Graham Lecturer at Princeton University and the Eysen Lecturer at the University of Louvain; Associate Professor Tirole was the recipient of a Sloan Research Fellowship which provides research support for two years to young scientists; Professor Lance J. Taylor will give the first lecture to honor Nobel Laureate W. Arthur Lewis at the American Economic Association Meetings this next winter and the Marshall Lectures next year at Cambridge University; Professor Peter Temin will serve as Pitt Professor of American History and Institutions at Cambridge University next year; and Institute Professor Franco Modigliani will be the next Killian Lecturer.
Program efforts this year were focused on a year-long seminar on the study of material culture, with a view to determining research strategies in this field which is again becoming an important anthropological concern, and is central to the work of several members of the Program. We also co-hosted the eighth annual Ethnobiology Conference and opened the Paleoenvironmental Laboratory, both through the efforts of Dr. Frederick Wiseman. We are beginning a major revision of our undergraduate subject offerings in light of the new initiative in humanities education at MIT.

Program faculty continued to be productive in their research endeavors. Two colleagues were in the field: Professor James Howe in Washington, D.C. and Panama doing archival and field work on the Marsh Darien Expedition, and the Kuna Revolution of 1924-25, while his book on The Kuna Gathering: Contemporary Village Politics in Panama was accepted for publication; and Professor Suzanne De Atley in Japan studying the ethnoarchaeology of village pottery production, while her co-edited book entitled Exploring the Limits: Frontier and Boundaries in Prehistory appeared. The faculty at home worked and published papers on a very wide variety of topics. Professor Martin Diskin on agrarian reform in El Salvador, ethnic autonomy in Nicaragua, and indigenous economic structures in Oaxaca, Mexico; Professor Jean Jackson on gender roles in various societies, and on the building of therapeutic communities as observed in the Boston Pain Center. Professor Heather Lechtman continued her work on the properties of copper-arsenic alloys and their uses and methods of manufacture in ancient societies; Professor Arthur Steinberg on the revolution in 16th century Venetian painting technique and style and, with Professor Jonathan Wylie on the social context for that change. Professor Sharon Traweek continued work on gender in science and technology, and on the ethnography of high energy physicists in the US and Japan, on which she finished a book-length manuscript. Dr. Wiseman did pollen studies in both the Maya area and colonial North America as well as more general work on agriculture and vegetation dynamics of the Maya collapse; and Professor Wylie has a book in press entitled The Paroe Islands: A History of Social Change and Cultural Continuity, and continues work on the origins of the Creole language and on Caribbean marine ecosystems.

Among honors received by the Program faculty are Professor Howe's fellowships from the National Endowment for the Humanities and the Woodrow Wilson Center, and Professor De Atley's Research Associate position at the Smithsonian Institution. Professor Diskin became chairman of the Latin American Studies Association's Task Force on Human Rights and Academic Freedom, and testified before a Congressional Subcommittee on the situation in El Salvador. Professor Lechtman was elected Vice President of the Institute of Andean Research, and continues as member of visiting committees to various departments at the Metropolitan Museum of Art, and the Boston Museum of Fine Arts. Professor Steinberg continued as Visiting Scholar at the Conservation Center of the Fogg Art Museum.

The only personnel change this year was Professor Diskin being promoted to full professor.

Visitors to the Program this year included Professor William Durham from Stanford University studying the Kuna language and preparing for his field trip to Panama; Dr. Frank Dubinskas, Visiting Scholar, studying research and development environments in biotechnology; and Dr. Michael Folsom, Director of the Charles River Museum of Industry, taught a subject in industrial archaeology.
Foreign Languages and Literatures Section

Program

The teaching of foreign languages and literatures continues to attract large numbers of undergraduates under the Institute's Humanities, Arts, and Social Sciences Requirements. Approximately 17 percent of the class of 1985 concentrated in one of the languages that we offer, the second largest concentration in some 25 fields. Enrollments continue at the same high level as last year, the largest of any of the HASS fields.

Because a number of growing problems and issues had pressed on the Section over recent years, Dean Friedlaender appointed an Ad Hoc Committee composed of a distinguished group of language scholars: Jean-Jacques Demorest, Professor of Romance Languages and Literatures, University of Arizona, Chairman; Mary Ann Caws, Professor of Romance Languages and Literatures, CUNY; and Sander Gilman, Professor of Germanic Languages and Literatures, Cornell University. The Committee reviewed the programs and personnel of the Section, spent two intensive days in interviews and discussions, and submitted a thoughtful report in May. The report was optimistic with regard to the faculty and programs of the Section, pointed up many of its problems, proposed ways of dealing with them, and indicated an important new initiative. Two proposals of special significance were (1) the creation of a new subgroup in addition to the present five of French, German, Russian, Spanish, and English as a Second Language, that would be concerned with the "over-arching theoretical and pragmatic questions of second language acquisition"; and (2) that the tenure of lecturers should be unlimited.

Both of these proposals as well as the whole report will be under intensive discussion over the next year. Steps are being taken at the present time to move in the direction of some of the Committee's recommendations. Research in foreign language acquisition is being centered under a new unit called the Foreign Language Studies Research Group under the direction of Senior Lecturer Claire Kramsch. The Athena project under the direction of Dr. Janet Murray that proposes to develop new software for computer-based second-language instruction is the kind of research effort that could be fitted into this new group.

The second step, taken after discussions by the School Council of a report on lecturers, would lengthen the maximum term of residence of lecturers from the present seven to nine years unless appointed to some other position.

Research

The faculty's involvement in research has continued at its previous active levels. Several volumes were published this year: Associate Professor Isabelle de Courtivron's, Violette Leduc: A Critical Study; Professor Robert E. Jones', H.-R. Lenormand; Professor Krystyna Pomorska's jointly edited festschrift to Georgii Lotman, Semiosis and her jointly edited volume, Roman Jakobson, Verbal Art, Verbal Sign, Verbal Time.

Personnel

It is a pleasure to report that Associate Professor Catherine Chvany was promoted to Professor, that Associate Professors de Courtivron and Elizabeth Carrels were granted tenure, and that Kathryn Crecelius was promoted to Associate Professor. New appointments this year were Joseph Brami as Assistant Professor of French and Robert Di Donato as Lecturer in German. The latter was also honored this year by being nationally elected 2nd Vice President of the American Association of Teachers of German which, in time, will automatically make him President.

E. CARY BROWN
The year 1984-85 was marked for the History Faculty by the arrival of two new assistant professors: Michael McGerr, a specialist in American political history who began teaching in the fall term, and Sarah Deutsch, an American social historian, who arrived in January. Both received their Ph.Ds from Yale. Their presence helped compensate for the absence of three Faculty members in the spring term, all of whom were on sabbatical leave. Arthur Kaledin used the time off from teaching to complete the draft of a book on Alexis de Tocqueville. Harald Reiche completed two articles and made further progress on a projected book tentatively titled New Light on Ancient Cosmology: Stonehenge to Plato. Robert MacMaster, a Tolstoi scholar, pursued his research in the Soviet Union under a grant from the International Research and Exchanges Board.

It should be noted, too, that within the past year another member of the History Faculty, Peter Perdue did research in Beijing, China, under a grant from the Committee for Scholarly Communication with the People's Republic of China (PRC). Professor Perdue was originally scheduled to begin work in China during September 1983. In late August, however, he received word that the Qing History Institute at the People's University had refused his application for affiliation, which meant he could not receive a visa to enter the PRC. Due in good part to the intervention of Provost Francis Low, Professor Perdue was finally granted access to the relevant archives and to the PRC, and was able to work in Beijing from March through August 1985. On the basis of that work he completed, in the spring of 1985, a book-length manuscript on "The State and Agriculture in Ming-Qing China (1500-1850)."

Aside from several articles and reviews or review essays, two books were published by members of the History Faculty during the past year: Bruce Mazlish's The Meaning of Karl Marx (Oxford University Press), and Pauline Maier's The American People: A History, an eighth-grade textbook brought out by D.C. Heath and Company. Robert Rotberg's South Africa and its Neighbors: Regional Security and Self-Interest is scheduled for publication by Lexington Books next year, when Oxford University Press will publish Michael McGerr's The Decline of Popular Politics: The American North, 1865-1928, a book that traces a dramatic decline in American voting participation between the 19th and 20th centuries to profound changes in the nature and practice of partisian politics. McGerr has also been brought under contract to write the seventh volume, on the period from 1900 to 1933, of the prestigious new Oxford History of the United States edited by C. Vann Woodward, an assignment that brings considerable honor on McGerr, who will be the youngest contributor to the series. Philip Khoury -- who will be promoted from assistant to associate professor on 1 July -- completed a massive manuscript on The Politics of Nationalism: Syria and the French Mandate, which has been accepted by Princeton University Press. David Ralston also recently completed his longterm study of the spread of European military techniques and institutions to the non-European world between 1600 and 1914, which he anticipates will be published shortly.

Members of the History Faculty continue to serve on the editorial boards of several prominent journals including Reviews in American History, Political Psychology, and the Journal of Interdisciplinary History, which Robert Rotberg still edits. They also hold a number of positions in professional organizations: Professor Rotberg completed a term on the council of the American Historical Association (AHA) last year, and Pauline Maier is on the AHA Nominating Committee, of which she is the 1985 chair and so responsible for the Association's national election, the ballots for which will begin arriving at MIT in the fall. Richard Douglas serves on the executive committee of the New England Renaissance Conference; Philip Khoury was elected to the 1985 Nominating Committee of the Middle East Studies Association of North America, and is an appointed fellow of the Aspen Institute for Humanistic Studies this summer; Bruce Mazlish served as a Section Head for last year's annual meeting of the International Society for Political Psychology.

The most formative event of the year may, however, have been the arrival of two new IBM PCs, along with the anticipated arrival of new software that should help move the History Faculty from the age of number-two pencils to the high tech era. Enthusiasm for using computers for analyzing historical data both for their own research and for pedagogical purposes is highest among the youngest members of the Faculty. It is hoped that, with the requisite hard and software available, members of the Faculty will become increasingly adept at using modern technology for historical study and be able to participate more fully in programs at the Institute such as UROP and Project Athena.

PAULINE MAIER
Considering that the Literature Faculty numbers only fifteen, one can say that this year its output of publications, invited lectures and outside services was prodigious. Here in summary form is a partial account of what its membership has been up to during the 1984-85. Articles were accepted by or appeared in the following professional journals: Massachusetts Review, Kenyon Review, New England Review, Dickens Studies Annual, Women's Studies, Ancient Philosophy, Yale Review, Paidia, Qualitative Sociology, Cinema Journal, Critical Studies in Mass Communications, Antaeus, Radical Teacher, the William Carlos Williams Newsletter. Chapters for books published by the following publishers were either accepted or made their appearance: Macmillan, Princeton University Press, Methuen, Associated University Press, New York University Press, Ohio University Press. Fictions by members of the Literature Faculty appeared in Story Quarterly, Partisan Review, New Oregon Review, and Passages North. Reviews were either accepted by or appeared in Conradiana, History and Theory, Renaissance Quarterly. Poetry appeared in Prairie Schooner, The Agni Review, Ploughshares, Hubbub, and The American Poetry Review. Translations of poems appeared in Epoch and Bluefish. Three books were either accepted for publication or published: a novel by Professor Gurney, a critical study by Professor Lang of the figure of Anne Hutchinson in American literature, and a volume of Pablo Neruda's sonnets translated by Professor Tapscott. Three books were completed: a lengthy study of Machievelli by Professor Donaldson, a study of the Renaissance theater by Professor Mullaney, and a monumental critical biography of Emily Dickinson by Professor Wolff; the latter two were under contract by the University of Chicago and by Knopf, respectively, and may be regarded as accepted for publication. Two full-length plays by Professor Gurney were accepted for production in New York City in the Spring of 1986. Invited lectures were given under the sponsorship of the following universities or professional societies: Modern Language Association (six lectures), English Institute, International Congress of the History of Science, Hebrew University of Jerusalem, Center for the Study of American Evangelicals, University of Lille, University of Padua, Universities of Mexico, Illinois, Wisconsin, Southern California, Iowa, and San Diego, California State at San Francisco, Stanford University, Smith College, Michigan State, American Philological Association, Society for Cinema Studies, Banff International Television Festival, Association for Speech Communication, Renaissance Society of America, Renaissance Conference on Drama, and the Shakespeare Association. Members of the Literature Faculty were active in editorial or consultational capacities for the National Endowment for the Humanities, the American Council of Learned Societies, the Hubbell Awards Committee, the Selection Board of the Literary Classics of the United States, the Presses of the University of Chicago and The Catholic University of America, the University of Michigan, and the University of Wisconsin. Published work appeared in the following professional journals: Modern Language Notes, Shakespeare Quarterly, Signs, Radical Teacher. Finally, we list the following honors received: Election to the Council of the Dramatists' Guild (Gurney), Research Associateship to Harvard Divinity School (Lang), appointment to the National Humanities Center (Halperin), Visiting Professorship, Institute for Advanced Study at the University of Illinois (Thorburn), NEH fellowship and appointment as Writer-in-Residence at the Rockefeller Foundation (Tapscott), Second Prize in the annual Cosmopolitan Magazine Short Story contest (Hildebidde).

I believe that this register of achievements and productivity would do credit to a faculty twice our number. Paradoxically, however, our professional success has intensified a long-standing problem. The Literature Faculty is deeply committed to its program of undergraduate education, which offers the only tiered curriculum in the Department of Humanities (leaving out of account programs designed to communicate a progressively acquired skill, such as a mastery of a foreign language). Sustaining this curriculum requires a minimum of thirty sections offered each semester in approximately twenty-five subjects; and this means engaging the services full-time of fifteen faculty. Our increasing professional success, however, also means that an increasing number of opportunities for professional development (fellowships, visiting appointments, and the like) comes our way each year, which it would be unwise to ignore. The result is that fewer of the fifteen full-time faculty members are available each year for staffing than the curriculum actually requires. (For example, fully one-third our number will be on leaves of absence next year.) In these circumstances, we must make several ad hoc temporary appointments each year, utilizing funds made available by unpaid faculty leaves. The loss in continuity, both to ourselves and to the students, is considerable, and there is also a loss in quality, since it is virtually impossible to attract applicants of high professional caliber to these temporary appointments. The situation will be helped by the appointment this year of Professor Rita Goldberg, the author of a book on Richardson and Diderot, but it remains serious and we are uncertain how to address it.

We are pleased to report the promotions of Professors Merritt and Thorburn to the rank of Professor, the award of tenure to Professor Halperin, and the appointment of Professor Wolff as the first holder of the Class of 1922 Professorship.

ALVIN C. KIBEL
This has been a productive year for the Music Section in all its various activities.

**PROMOTIONS AND STAFFING**

Professors Marcus Thompson and Barry Vercoe were promoted to Full Professor, reflecting the international recognition each has achieved, as well as the depth and breadth of their contributions to the Institute and to the Section's academic program. Nancy Cavanagh was promoted to Administrative Officer of the Section.

The experiment with the annual change of Section chair has now gone through four rounds; Professors John Harbison, David Epstein, Marcus Thompson, and this year, Jeanne Bamberger have served a one-year term. Next year Professor Lowell Lindgren, the last of those eligible, will take over the chair. The experiment has succeeded in exposing all of us to a wider perspective, offering a range of foci due to the varied interests of each incumbent, and providing a cohesiveness to the management of the Section as each of us "learns the ropes." Further, with Ms. Cavanagh as our Administrative Officer, there is assured administrative continuity in the midst of change. With next year the last in the "round robin," serious discussions have already begun concerning the future course of leadership for the Section.

**ACADEMIC AND PERFORMANCE PROGRAMS**

The total enrollment in music courses generally remained steady at 852 students. Of special interest is the extraordinary influx of highly talented musicians among our undergraduates. In response to the students' enthusiasm for doing music, Jane Coppock has designed a new course, 21.649 Musicianship for Performers, to give students an opportunity to study musical structure from the view of its practical application to their own performance activities. Professor Thompson's work with the Chamber Music Society and the MIT Chamber Players, as well as his course offering, 21.658 Advanced Music Performance, continue to encourage the students' interest and their high level of performance. Advanced Music Performance is open only to the most gifted performers. In the context of this subject, 10 students studied privately with master teachers in the area and also attended monthly seminars conducted by Professor Thompson. Next year several members of the faculty in addition to Professor Thompson will participate in these seminars, not only to broaden their base but also to provide a common ground for faculty interaction. Students in 21.651 Vocal Repertoire and Performance, taught by Senior Lecturer, John Oliver, will participate in these all-faculty seminars as well.

In addition to those students involved in private study for credit, 12 students received partial scholarships for private, non-credit instruction. Students in both programs performed with one or more of the Section's musical groups. As a result, the level of performance in all the performing groups has been exceptionally high. One example is the stunning performance of Stravinsky's L'Histoire du Soldat in which the professional musicians in the MIT Chamber Players worked side-by-side with students in the Advanced Performance class.

Support for private performance study has come from the Ragnar and Margaret Naess Music Fund and the Rudolph Gruber Fund, through a special arrangement with the New England Conservatory, and a generous grant from the Council of the Arts at MIT. While we are grateful for these contributions, the program has proved so vital in attracting outstanding students to MIT, it is essential that future support for gifted performers be included as a regular item in the Section's budget.

Other performing groups also distinguished themselves this year. The MIT Symphony, conducted by Professor Epstein, commissioned and brilliantly performed at its spring concert a new work for orchestra and tape-recorded, computer-generated sound composed by Peter Child. The MIT Choral Society, conducted by Senior Lecturer Oliver presented a performance of Handel's Messiah to a sold-out house, and the Festival Jazz Band, directed for the past 22 years by Affiliated Artist I. Herbert Pomeroy, again won first place in national competition at Notre Dame University, making the Band a real "frontpiece" for MIT musical activities. Next year Mr. Pomeroy will take a much deserved reduction in work load and will oversee an interim conductor for the Festival Jazz Band, Affiliated Artist, Jamshied Sharifi. Mr. Sharifi is a Course XXI graduate of MIT and a former member of the Band.

The wealth of talent and the rather extraordinary level of activity among the students presents us and them with a serious space problem. In order to continue to foster student enthusiasm and, indeed, their attraction to MIT, we must provide them with adequate practice and rehearsal space. We consider such action a first priority if the success of our performance programs is to continue.
In other developments, Professor Vercoe has moved his Experimental Music Studio into the new Arts and Media Technology Building. In addition to a marked upgrading of technical facilities, the enlarged space includes offices for staff and graduate students, and properly equipped labs for the Studio's expanding research programs. This year the first Ph.D. student entered his program and next year he expects two more. While these activities are officially under the aegis of the Department of Architecture, students enrolled in the undergraduate and graduate courses offered by Professor Vercoe in the Music Section, will clearly benefit from the expanded presence of his Lab and his ongoing research.

FACULTY ACTIVITIES

Performers and composers on our faculty have been active world-wide. Professor John Buttrick recorded the works of Reger and had a successful concert tour in Germany and Switzerland; Professor Epstein's New Orchestra of Boston performed at the Mozarteum in Salzburg, Austria and at the International Festival of the Azores. Professor Stephen Erdely of the Erdely Duo recorded works by Milhaud and Enesco. Professor Thompson appeared with the Boston Chamber Music Society, Banchetto Musicale, and as soloist at the Sitka Summer Music Festival in Alaska and the Dubrovnik Festival in Yugoslavia; and Professor Vercoe "stole the show" in Paris at the Institute for Research and Coordination Acoustics/Music (IRCAM) with his demonstration of a new work-in-progress for live flute and computer-following accompaniment. Professor Harbison's compositions were performed by orchestras and chamber music groups in Springfield, Houston, at the Kennedy Center in Washington, Lincoln Center in New York, and at Tanglewood where he was composer-in-residence during the summer of 1984. In addition, his Variations were published and his Symphony recorded by New World Records. Senior Lecturer, Edward Cohen, received a commission for a new work, Fantasy, which was performed in April by Collage.

Professor Lindgren edited a book, Giovanni Bononcini, Twenty-four Cantatas and One Serenata, for which he wrote the introduction and also transcribed the texts. He continues as review editor for the Journal of the American Musicological Society. Professor Bamberger has received a grant from the Spencer Foundation to write a book, The Development of Musical Intelligence and has participated in two television productions—one with the BBC and the other for Nova—concerning musically gifted children. She is also responsible for a grant from the Apple Corporation to the Cambridge School Department. The grant will provide the necessary technology for a new research project in a local public school.

Regrettably I report the passing of John Cook who served as our first Institute Organist and later as Lecturer in Music. Mr. Cook was a composer as well as a performer and teacher, and two of his works were performed by the current Institute Organist, James David Christie, at a memorial service held last fall.

JEANNE BAMBERGER
The Writing Program continues to perform a vital teaching service at the Institute. The Program's curriculum has achieved a depth and balance appropriate for the diverse student population. The current undergraduate subjects in expository writing, creative writing, and science and technical writing, still draw a steady enrollment of students at all levels, advanced and beginning alike. Many subjects are used to 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, have maintained their enrollments and are expanding to new departments in the School of Science. The summer session short-course, "Communicating Technical Information," has reached record levels of popularity with many students from industries throughout the world.

In addition to offering an academic curriculum for the student body, the Program has continued to bring to the larger MIT community distinguished writers and poets who share their ideas about their work and the craft of writing. The science fiction lecture series, "1984 and counting . . . ," featured Jack Dann, Thomas Disch, Gardner Dozois, Joe Haldeman and Joan Vinge, and proved popular with the MIT community during the fall term. The New American Poets Series, which featured Marea Gordett, William Pitt-Root, Laurence Lieberman, and Pamela Alexander, is particularly noteworthy for the tremendous response and praise it received during the spring term. Helen Edmonds, a Visiting Scholar with the Program this year, is presently completing a book on black women in politics. During her stay at MIT, she shared her work and experiences with the entire community.

Several faculty have worked diligently over the past year to increase their professional activity and accomplishments. Bernard Avishai and Harriet Ritvo were promoted from Assistant to Associate Professor. Avishai's book, The Tragedy of Zionism, will be published during the summer; Ritvo's book, The Rise of the Animal Estate will be published soon, too. In addition, the faculty have received a number of other honors this year. Robin Becker won the Massachusetts Artists' Fellowship Award in poetry; she will be on leave during the spring term next year on an Old Dominion Fellowship. Harriet Ritvo won a Research Fellowship from the Stanford Humanities Center, and she will spend the next academic year at Stanford extending her study of animals in Victorian England. Kenneth Manning won the Pfizer Award of the History of Science Society for his book, Black Apollo of Science.

The Program's faculty has been developing stability as the number of part-time staff have been reduced in favor of full-time appointments. Several key appointments of new faculty and staff occurred over the last year. The renowned and prize-winning science fiction writer Joe Haldeman, who had been teaching with us on an ad-hoc arrangement, will join the Program as Adjunct Professor of Science Fiction in the Fall. Thomas Pearsall, a leading expert on technical writing, will be Visiting Professor of Technical Communication for the fall semester. Janette Hospital, a distinguished novelist and short story writer, will be joining the Program for the academic year as Visiting Writer. Marcel La Follette and Rosalind Williams, both published writers with growing reputations, have been appointed as Assistant Professor. Janet Murray will join the Program as Principal Research Scientist, to help secure funds and become principal investigator for the Writing Program's Athena Project. Charles Fuller assumed the new position of administrative officer for the Program.

The Program launched a new Course XXI major in science and technical writing, in part to allow students to prepare for the many opportunities for professional careers in technical communication. The Program's Athena proposal was approved by the Project Athena Committee, and once funded and under the supervision of Janet Murray, this project on the various aspects of computers and writing will also present our faculty and staff with a new venture for the coming years. The Writing and Communication Center, a popular and effective resource in the MIT community, secured long-term funding this past year, and under the talented direction of Steven Strang, the Center will surely continue to provide high quality service.

The above programs and projects, among others, were the results of the creative planning, work, and leadership of James Paradis, who went on sabbatical last spring and will return next spring. He is completing a major textbook on technical communication. Kenneth Manning served as acting head for the spring semester and has agreed to stay on as head.

KENNETH MANNING
One of the Department's greatest concerns continues to be financial support for graduate students. The Linguistics program has maintained its number one ranking, the Philosophy program has moved up to eighth place, and the Department will undoubtedly continue to attract the best students. But trying to find ways to remain competitive with other top schools in offering financial assistance remains problematic. There are relatively few sources of support for theoretical linguistics and philosophy. The Department will have to give special attention to this problem in the near future.

Research: Linguistics

Work in linguistics has focussed on the three major areas: syntax, semantics, and phonology. The primary topic of research in syntax has been Government and Binding theory. Work on the nature and structure of logical form has been of major importance in semantics. In phonology, continued exploration and development of the theory of hierarchical phonology has commanded the most attention.

In addition, the Department is pursuing a new line of inquiry. A great deal of time and attention is currently being given to the lexicon, particularly to the question of the form of a lexical entry. This research, in conjunction with work ongoing in the Center for Cognitive Science, is developing in new and interesting ways and promises to be an extremely fruitful area of research in the years ahead.

Research: Philosophy

In philosophy, research activity focussed on such topics as: the foundations of set theory; various studies of scientific change; philosophical, literary, and scientific concepts of human affect; an eretetic approach to learning and scientific development; the understanding of the origins of modern philosophy; and Rousseau's political philosophy.

Publications

As in previous years, faculty members presented papers and attended colloquia at home and overseas. Faculty from both sections had articles, reviews and books published during the past year. The four books published were: Noam Chomsky, Radical Priorities (C. Otero, ed.), Montreal: Black Rose Books (second revised edition); Modular Approaches to the Study of the Mind, San Diego: San Diego State University Press (First Distinguished Graduate Research Lecture - 1980). Luigi Rizzi, Teoria Grammaticale e Spiegazione, Padua, Italy: CLESP. Irving Singer, The Nature of Love: 2, Courtly and Romantic, Chicago: University of Chicago Press.

Honors and Awards

Two faculty members were invited to deliver series of lectures at Johns Hopkins University. In November, Professor Thomas S. Kuhn gave four Thalheimer Lectures on "Scientific Development and Lexical Change." In April, Professor Irving Singer gave three lectures on "The Meaning of Life and Death." In addition, Professor Kuhn was invited to spend the month of June at the Ecole des Hautes Etudes en Sciences Sociales (EHESS) in Paris where he lectured and conducted seminars on his current work.

Professor George Boolos was appointed Chairman of the Advisory Council (Visiting Committee) of the Department of Philosophy at Princeton University. Professor Kenneth Hale was nominated to the Executive Committee of the Linguistic Society of America.

Professor John Carriero, a first-year member of the faculty, received the Adams Dissertation Award from Harvard University. This award honors a recent Ph.D. recipient in philosophy whose dissertation is considered to be of the highest degree of excellence.

Professor Wayne O'Neil has been named Honorary Professor of Linguistics at Shandong University, Jinan, People's Republic of China.

Leaves of Absence

Professor Morris Halle spent his sabbatical as an Associate of the EHESS in Paris where he jointly taught a course on modern phonology. He was also invited to give papers at Stockholm, Gothenburg and Lund Universities; the Linguistic Circle of Copenhagen; the University of Venice and Scuola Normale Superiore; Nice and Provence Universities; the London School of Oriental and African Studies, and Essex and Sussex Universities; and the University of Saarbrücken.
Professor Ned Block spent the year at the Center for the Study of Language and Information, Stanford University. Professor Jerry Fodor spent the second term teaching at the University of California, Berkeley.

Professor Judith W. DeCew spent the year on a research fellowship from the American Council of Learned Societies. Only five philosophers received fellowships; of these five, Professor DeCew was the only junior philosopher to receive one.

Personnel

The Department has appointed three new faculty members: Richard Kayne, Professor of Linguistics, whose major research is in Theoretical Linguistics and Romance Syntax; Richard Larson, Assistant Professor of Linguistics, whose interests lie in Semantics and Syntax; and Scott Weinstein, Associate Professor of Philosophy, whose areas of specialization include Formal Learning Theory, Logic, and Philosophy of Mathematics. Professor Larson's appointment was the Institute's second appointment in cognitive science (Professor Steven Pinker in Psychology was the first) and was made under the auspices of the Center for Cognitive Science.

On July 1st, Professor Samuel Jay Keyser will take up his new post as Associate Provost. The Department is extremely fortunate to have Professor Richard Cartwright as his successor as Department Head. Professor Morris Halle will assume the duties of Chairman of the Linguistics Section, and Professor Jerry Fodor will continue to serve as Chairman of the Philosophy Section.

I would like to add a personal note as I end my tenure as Department Head. Working with first-rate linguists and philosophers and getting to know so many very talented graduate students has been a great pleasure. I hope that my initial attempts to provide more support for graduate students will bear fruit in the future. There are so many people I would like to thank whose help over the years has been invaluable and who have made my responsibilities as Department Head manageable. I especially wish to express my gratitude to Marilyn Silva, Administrative Officer, without whom the task would have been impossible. My thanks go to her and to everyone who has made the past eight years the most rewarding of my academic life.

SAMUEL JAY KEYSER
Department of Political Science

After many years of remarkably low turnover, the Department has entered a period of considerable change. Last year we had to report the retirement of Professor William W. Kaufmann and the death of Professor Ithiel de Sola Pool, as well as the departure for other positions of three junior faculty members. To that list must now be added two additional names. Professor Alan A. Altschuler, a leading analyst of transportation and other domestic policy issues as well as former Head of the Department, has resigned in order to continue as Dean of the Graduate School of Public Administration at New York University. Professor Altschuler's decision was no great surprise, since he had been on leave from the Institute in his new position during the previous year, but we had hoped that he might rejoin the Department. His departure deprives us of an outstanding colleague and scholar who had contributed greatly to building up the public policy dimension of the Department's work. A long-time collaborator in that enterprise, Associate Professor Martha W. Weinberg, also submitted her resignation this spring, following a period of leave at the Harvard Business School.

Not surprisingly, a large share of the Department's energies has been invested this year in recruiting replacements. Searches were conducted in three specific fields: American politics, empirical methodology, and arms control and defense. Two Assistant Professors were appointed in American politics, Charles Stewart from Stanford and Richard Valelly from Harvard. Dr. Peter Lemieux, a specialist in communications policy as well as in empirical methods, has been appointed as Lecturer. No appointment was made in Arms Control and Defense, but that search will continue next year. A more general search was also undertaken for a senior political scientist to strengthen the Department in one of several possible fields and help compensate for recent losses. A leading candidate has been identified, with a response to our invitation expected shortly.

The Department continues to suffer from inadequate financial assistance for graduate students. Relative to other leading departments, we can offer incoming students far fewer tuition fellowships, as well as fewer and less generous stipends. This has put us at a distinct disadvantage in competing for the best among each year's applicant pool. Some progress has been made this year as a result of procedural and policy modifications that give us greater flexibility in the use of departmental and Institute resources, but a major breakthrough will require fresh funds. A finding to this effect has been made by a committee chaired by Professor Myron Weiner that undertook a detailed analysis of graduate student financial aid in this School. While all the departments in the School have a genuine need, it came as no surprise to us that the need in Political Science was estimated to be about twice as great as that of any other department, and about half the School's total estimated need. It would make a substantial difference to the quality of life in this Department if tangible steps were taken to deal with this question.

Although space does not allow a summary of developments in all of the Department's major fields of research and teaching, some highlights may be mentioned. One of the most flourishing of our substantive fields is Defense and Arms Control, reflecting both the national attention being given to international security issues and the long-standing excellence of our graduate program in this field. The Center for International Studies, which houses the faculty and graduate students in this program, has this year received grants from the Carnegie Corporation and the Hewlett Foundation, supplementing grants received earlier from the Ford Foundation, in support of the Arms Control and Defense Program's work. Funds have also been given by the Department of Defense to support Associate Professor Stephen M. Meyer's research on the Soviet military. From the Department's standpoint, the critical contribution of these grants comes in the form of partial fellowships and research assistantships awarded to nearly twenty graduate students. This represents the largest clustering of students specializing in any given area of the Department, and the faculty members in this field -- Professor George W. Rathjens, Professor Meyer, and Professor Jack Ruina of the Electrical Engineering and Computer Science Department -- have been hard pressed to meet the internal and external demands on their time. We are responding to the need both by making new appointments and by encouraging faculty members in other parts of the Department to develop new courses relevant to international security matters. Professor Hayward R. Alker, Jr. has developed a new undergraduate subject on Just Wars, Total Wars, and Nuclear Wars; Professor William E. Griffith is teaching a graduate seminar on European Security matters; and Professor Harvey M. Sapolsky is offering a graduate seminar on Defense Politics. New subjects are also being taught by Steven E. Miller, who has joined us as a Lecturer (soon to be Assistant Professor) after several years as editor of the journal International Security. We hope to make an additional appointment in this field next year.
Research and teaching on Third World countries continue to flourish. Professor Lucian W. Pye, one of the country's leading China specialists, has completed a book on Asian Power and Politics to be published later this year. Professor Weiner has continued his work on Indian politics while deepening his more recent interest in the effects of large-scale movements of people from one country to another. He and Professor Nazli Choucri are collaborating on a series of case studies involving migration in the Middle East and South Asia. Excellent progress has been made toward the development of a first-rate program in Latin American studies. Under the leadership of Professor Peter H. Smith and Associate Professor Brian H. Smith, new subjects have been developed, outside funding sought, and a small but excellent group of graduate students recruited. Latin America has been a relatively underdeveloped field of study until recently, both in the country as a whole and at MIT, and it is gratifying to see the Department begin to assume a prominent role as a center for research and training in this field. By contrast, African studies have tended to attract relatively low levels of student interest and research funding here and nationwide, a condition that recent intensified concern about the South African situation may perhaps change. Professor Willard R. Johnson has been actively engaged in efforts to educate the public about South Africa by serving as national co-chair of the Association of Concerned African Scholars and by helping organize the Free South Africa Movement in Boston. He has also continued his research and writing on communications and rural development in Africa, especially Cameroon. Professor Robert I. Rotberg has lectured widely here and in Africa on international policy toward South Africa and has co-edited a book on South Africa and Its Neighbors: Regional Security and Self-Interest.

Political and economic issues in advanced industrial societies have been receiving increased attention lately. For many years Professor Suzanne Berger, specializing on Western Europe, was the only Department member centrally concerned with the problems of industrial societies other than the United States. In collaboration with Professor Michael Piore of the Economics Department, Professor Berger has led the way in developing a new field of Political Economy — primarily though not exclusively centered on issues of industrial society — that has proven highly attractive to graduate students. The addition of Associate Professor Charles F. Sabel to the Department's roster last year is another major step in the development of this area, adding strength on labor issues and, more generally, on historical and sociological aspects of European political economy. Professors Sabel and Piore collaborated on a book published last fall, The Second Industrial Divide: Possibilities of Prosperity. Japan is represented as well in this sphere of activity. Associate Professor Richard J. Samuels is combining his expertise on Japanese politics and international energy issues in the writing of a book on the role of the state in Japanese energy policy; he returned from a year's research leave in Japan last fall to a new appointment as Mitsui Career Development Professor in Contemporary Technology.

It gives me pleasure, finally, to report some honors and awards received by members of the faculty. Professor Berger has been appointed Ford International Professor of Political Science; she has also been named holder of the French-American Foundation Chair in American Civilization for 1985-86 and will teach at the Ecole des Hautes Etudes in Paris. Professor Walter Dean Burnham, a leading analyst of American elections and political parties, has been named Ruth and Arthur Sloan Professor of Political Science, filling the chair left vacant by Professor Pool's death. Professor Choucri was elected a member of the Council on Foreign Relations. Associate Professor Joshua Cohen was awarded research fellowships for next year from the National Endowment for the Humanities and from the American Council of Learned Societies. Professor Michael Lipsky was asked to join a Committee on the Status of Black Americans of the National Research Council of the National Academy of Sciences; he has also testified this year before three committees of the House and Senate in connection with his current research on hunger and U.S. food policy. Professor Sapolsky has been serving as Senior Counselor to a National Academy of Sciences committee convened to restructure the Institute of Medicine. Professor Eugene B. Skolnikoff has been elected to the AAAS Committee on Science, Engineering, and Public Policy and has begun a regular book review column on international and science policy in the new journal of the National Academy of Sciences, Issues in Science and Technology. Associate Professor Deborah Stone was awarded a Guggenheim Fellowship and a Harvard Liberal Arts Fellowship in Law; her book on public policy toward disability, The Disabled State, was published in December.
Department of Psychology

Personnel

We mourn the loss of Professor Norman Geschwind who, although only a part-time member of our faculty, was a source of inspiration, encyclopedic knowledge, and uninhibited wit. On a more positive note, we are pleased to acknowledge the promotion of Steven Pinker to associate professor with tenure, Daniel Osherson to full professor, and John Hollerbach to associate professor. Professor Mary Potter was elected Chair of the Faculty. Professors Carey, Fodor, and Ullman were on leave at the Center for Advanced Study in Behavioral Sciences in Palo Alto, Stanford University, and the Weizmann Institute in Israel, respectively. Professor Held received the Kenneth Craik Award from St. John's College at Cambridge University in England.

Educational

Our undergraduate program continues to increase in enrollment (up 23% from last year). The undergraduate major in cognitive science is now in its third year and has grown steadily during those years. Its steady state enrollment will depend upon the resources that become available to the department. The graduate program continues at steady state: five Ph.D.'s were granted during the year, and eight new students were admitted for the coming year. The quality of our graduate student group was demonstrated by the fact that, of the four students who applied for NSF fellowship support during the year, three received these prestigious fellowships and the fourth received honorable mention.

Professional Activities

Our faculty maintain their intense rates of publication, oral presentations at meetings throughout the world, and services to the profession. Our regular colloquia, lunch, and other meetings occur daily throughout the week and not infrequently more than once a day. As usual, attendance includes not only our own people but members of the local community as well. Many guest visitors spend time visiting facilities and in informal communication with staff and students.

Research

Despite increasing stringencies in the federal budget for support of research, our faculty continue to hold their own in the increasingly tough competition for support to maintain their laboratories. Problems are arising over the origin of certain of the grant proposals in which our faculty serve as principal investigators. Other entities such as Whitaker College and the Clinical Research Center, with which our faculty are associated, are either originating grant proposals from our faculty or requesting that they originate from their offices. To the extent that such awards do not go through the department, our research and staff personnel are reduced and our status as a research organization is lessened. The resolution of this issue requires administrative decisions which bear on the future of the department.

The Future

It has become apparent to many observers at the Institute and elsewhere that we are witnessing the growth of an exciting new science dealing with intelligence in all its manifestations, both natural and artificial. When this department was formed in the early 1960's, its blueprint contained an inchoate beginning of this science in combining under one roof several of the most promising areas of research in the brain sciences. The innovative research efforts of our faculty over the last twenty years have brought them to exciting new frontiers, but the very success of these research efforts coupled with the diversity of the research directions within the department and the interdisciplinary nature of many of the problems under consideration bring us to a dilemma. Previous annual reports have alluded to the centrifugal forces acting upon this department and threatening to pull it apart. The diversity found within the department results in legitimate desires for autonomy by members of sub-groups such as the neuroscientists. In addition, affinity with other groups at the Institute, such as the Artificial Intelligence Laboratory, exerts pulls on some of our faculty.

The situation has now become critical. In the recent five-year plan, the department is described as consisting of four parts: systems neural science, cognitive science, natural computation, and vision science. Our neurosciences group together with new appointments in neurobiology are becoming increasingly autonomous. The computational group is divided in its allegiance. To the extent that these groups separate from the department and establish parallel programs we are weakened both intellectually and practically.

A related issue concerns the name of this department. Each of the four parts of the department ranks at least within the top five groups of its kind in the nation. Yet as a psychology department, a recent
survey of department chairpersons ranked us as twenty-third. In short, we can say that, paradoxically, the whole is less than the sum of its parts. Clearly the department is, in some sense, misnamed. Our faculty have discussed the subject at length and have concluded that the name, "Cognitive Sciences," would be more appropriate, although not without its problems. Our visiting committee has heartily endorsed this name change.

Yet a name change alone will not solve the problem. We need to maintain and expand communication and collaboration among groups at the Institute working on common problems in the area of intelligent systems. These groups exist not only in neuroscience, cognitive science, and in the Artificial Intelligence Laboratory, but also in the Department of Linguistics and Philosophy, speech and hearing, and include other individuals scattered across the Institute. Recently a consortium of administrators in these fields met and agreed that the time is ripe for serious development at MIT of cognitive science: inquiry into the nature of intelligent systems. Such a new initiative bringing together the enormous resources now scattered throughout the Institute, would have great appeal and fund-raising potential. With the support of the community, the department is prepared to play a key role in this development.

RICHARD HELD
The major news in the undergraduate teaching area, the main activity of the Program in Science, Technology, and Society (STS), is the first trial of the Integrated Studies Program (ISP). It offered a small group of freshmen an opportunity to combine the learning of mathematics and physics with a study of the historical, cultural, and social context in which Western science and technology have developed since the seventeenth century. This was done by having them take their mathematics and physics as a group, with the recitation sections scheduled as two blocks of two hours each and by asking them all to register for an ISP Humanities Distribution subject and one of several seminars taught by STS faculty.

The Program had a well-furnished lounge which the students and tutors used extensively in a way which promoted cohesion and solidarity among the students. The experiment was successful in all but one respect—namely, the number of students it attracted. Administration problems in the communications between ISP, the Freshmen Office and members of the incoming class explained, we believe, the small enrollments. We believe these have been resolved, and look forward to the results of the second offering next year.

Overall enrollments in STS courses held about steady.

STS's cooperative support of graduate students continued. Eleven graduate students were supported by fellowships and/or office space, of whom nine were enrolled in Political Science, one in Urban Studies and Planning, and one in Electrical Engineering and Computer Science.

RESEARCH AND HONORS

Professor Merritt Roe Smith spent half the year as a Regents' Fellow at the Smithsonian Institution. He edited a collection of essays on "Military Enterprise and Technological Change" to be published by the MIT Press in September 1985. Professor Smith contributed one of the essays as did Associate Professor Peter Buck. Professor Leo Marx was Chair of the Executive Committee of the Delegation of American Studies of the American Council of Learned Societies to the People's Republic of China in October 1984. Harley Shaiken, a research associate in the Program, published Work Transformed, Automation and Labor in the Computer Age. This study of the effects of automation in auto plants on labor-management relations has excited wide comment. Kosta Tsipis, Principle Research Scientist, continued his energetic activities in research and public education on arms controls problems.

THE MELLON FELLOWSHIP PROGRAM

The Mellon Fellowship Program supports researchers in engineering and science disciplines who wish to spend a year examining the problems of the social interactions of science and technology. The program, funded for five years by the Andrew W. Mellon Foundation, was begun in academic year 1983-84. There were four fellows this year—Peter Carney, Vilma Hunt, Judith Kroll, and Mark Levinson. Peter Carney, a neurosurgeon, worked on a report of his experiences as Chief of Neurosurgery at the King Faisal Specialist Hospital in Riyadh, Saudi Arabia, bringing high technology medicine to a medieval society. Vilma Hunt, Professor of Environmental Health at the Pennsylvania State University, studied the difference between military and civilian standards of exposure to radiation. Judith Kroll, Assistant Professor of Psychology and Education, Mount Holyoke College, received half-time funding to develop her interests in statistics and quantitative reasoning, the professional development of women in science, and the role of creative thought in science. She also had a half-time appointment as a Research Affiliate without salary in the Department of Psychology at MIT. Mark Levinson, Professor of Mechanical Engineering at the University of Maine at Orono, spent part of his time on a study of the early history of NCAA and part on the design of an STS program for the University of Maine at Orono.

THE EXXON FELLOWSHIP PROGRAM

The Exxon Fellows this year included Eugene Cittadino, Philip Fisher, Diane Paul, and Andrew Pickering. Eugene Cittadino, Assistant Professor at the School-Within-The-School and History Department at the State University of New York, Potsdam, spent the year doing research on the general problem of the relationship between biological science and social thought in the late 19th and 20th centuries. Philip Fisher, Professor of English and American Literature and Coordinator of the Humanities Program at Brandeis University, worked to complete a book on the consequences for art objects of the change within society from craft production to mass production. Diane Paul, Associate Professor of Political Science at the University of Massachusetts at Boston, used the fellowship period to write three linked articles on aspects of the history of eugenics and its relation to political thought in the 19th and 20th centuries. Andrew Pickering, a theoretical physicist by training working in the Science Studies Unit at Edinburgh, explored the implica-
tions of the sociology of knowledge approach to the history of science during his fellowship year. The Exxon Education Foundation funds this fellowship program for scholars in the humanities and social sciences to pursue researches in the history and social interactions of science and technology.

THE VANNEVAR BUSH FELLOWSHIP PROGRAM

The Vannevar Bush Fellowship Program in the Public Understanding of Science and Technology finished its second working year. The eight American science journalists who came this year were Lew Frederick (television news reporter for KGW television in Portland, Oregon), Paul Haskins (environmental and general assignment reporter for The Sentinel, the afternoon newspaper in Winston-Salem, North Carolina), Richard Hoppe (reporter for the Washington Bureau for McGraw-Hill World News), Jeanne McDermott (free-lance writer), Kristine Moe (science reporter for The Journal-American newspaper in Bellevue, Washington), Charles Petit (science correspondent, San Francisco Chronicle), Ellen Ruppel Shell (free-lance science and technology writer), and Laura Simmons (reporter for the Timesdaily, Florence, Alabama). In addition, for the first time one journalist from Europe and one from Japan joined the group. Horst Rademacher, a German free-lance writer came with support from the Robert Bosch Foundation, and we expect support for a German journalist to continue on a long-term basis. Seishi Koizumi, a science writer for the Yomiuri Shimbun, who came to MIT as a Fulbright Scholar, joined the group and shared their experiences. This program continues to exceed the anticipations of its participants in providing an intellectually stimulating and exciting year. Many of last year's alumni are regularly in touch with the Program and the Institute.

VISITING SCHOLARS

In addition, 19 visiting scholars from the United States and nine foreign countries came to work with the Program faculty and contribute to its seminars and discussions.

PROGRAM IN TECHNOLOGICAL LITERACY

This program, initiated by a grant from the Sloan Foundation and working under the leadership of Professors Margaret MacVicar and Leon Trilling, continued for its third year. Its major feature this year was the participation of Professor Donald Beaver (Williams College), Professor Thomas Longstaff (Colby College), Professor Earl MacCormac (Davidson College), and Professor Robert Martin (Middlebury College). As visiting scholars at STS, they also acted as tutors in ISP, bringing the experiences and perspectives of teachers in liberal arts colleges to MIT undergraduates.

CARL KAYSEN
The past year has been a time of growth in the program of the Center for International Studies, under the direction of Professor Eugene B. Skolnikoff, Political Science.

Arms control and defense policy have remained a central part of the Center's activities. Joining Professor Jack Ruina of Electrical Engineering and Computer Science, who directs the program, and Professors George Rathjens, Stephen Meyer, and William Griffith, all of Political Science, has been Professor Steven Miller of Political Science. Professor William Kaufmann of Political Science retired at the beginning of the year; he had been active in the program since the early 1960s. Others associated with the program during the year have been: Dr. Herbert Lin, Postdoctoral Fellow; LTC Theodore Schroeder, Air Force Visiting Scholar; Dr. Morton Halperin, Civil Liberties Union, Washington, D.C.; Dr. Bernard Kramer, University of Massachusetts; and Carol Cohn, The New School of Social Research.

A substantial body of the research conducted in the program is carried out by graduate students in meeting their degree requirements. In addition, Professor Meyer continued his work on Soviet decision making in defense and arms control. Professor Rathjens together with Ronald Siegel, a graduate student, began a study of the technical analysis and policy conclusions drawn by those who predict "nuclear winter" as a consequence of a US-Soviet nuclear exchange. Dr. Lin is preparing a manuscript on the Strategic Defense Initiative (the so-called Star Wars proposal) and Professor Ruina has prepared several papers on the technical dimensions of the arms race, including the Strategic Defense Initiative.

The program has continued to make the results of its work available to a broader community through seminars and publications, testimony before Congressional Committees, work with public interest groups, and advice to government agencies in the field. In collaboration with the Harvard Center for Science and International Affairs two summer workshops were offered, in July 1984 and in June 1985, for teachers from liberal arts colleges who offer courses to which arms control and defense issues are relevant.

The Center also played a key role in implementing a grant awarded to the Institute as a whole to assist MIT faculty and students not presently professionally engaged in study of arms control and security issues to work in the field. Professor Skolnikoff and Professor Carl Kaysen, Director of the Science, Technology, and Society Program, cochaired a committee that solicited project proposals from throughout the Institute and recommended to Provost Francis Low those to receive research support for the initial year. The committee was composed of Professor Donald Blackmer, Head of Political Science; Professor Jerome Rothenberg, Economics; Professor Jack Kerrebrock, Head of Aeronautics and Astronautics; Professor Philip Morrison, Physics; and Professor Ruina. Awards were made to Professor Hayward Alker, Political Science, for the development of computer models of the arms race for classroom use; to Dr. Eric Chivian, MD, Medical Department, for a comparative study of teenagers' views of nuclear warfare; to Professor Aron Bernstein, Physics, for a study of crisis control; to Professor Edwin Diamond, Political Science, for a comparison of media coverage of important arms control issues; to Professor Ira Dyer, Ocean Engineering, to support a study of ocean-related arms control issues; to Professor Thomas Jordan, Earth, Atmospheric, and Planetary Sciences, to develop ways to present nuclear test detection information to non-technically trained decision makers; to Professor Philip Khoury, History Faculty, Humanities, for a study of the impact of war in the Middle East; to Professor Jean Louis, Aeronautics and Astronautics, for an examination of approaches to curbing the arms race in space; to Dr. Marvin Miller, Senior Scientist, Nuclear Engineering, for work on nuclear proliferation; to Professor Harvey Sapolsky, Political Science, for a study of inter-service rivalries; to Professor Thomas Sherridan, Mechanical Engineering, for a study of the reliability of command and control systems; and to Professor Lance Taylor, Economics and Applied Biological Sciences, for work on arms and economic development.

The MIT/Japan Science and Technology Program has remained active during the year, under the direction of Professor Richard Samuels, Political Science, and Professor D. Eleanor Westney, Management. The program has the objective of increasing knowledge in the United States about scientific and technological developments in Japan by encouraging collaborative research, making Japanese literature more available, and giving technically trained MIT students an opportunity to work as interns in Japanese laboratories, universities, or industries and equipping them with the language skills and cultural knowledge to be able to do so. The program assisted in arranging for Japanese language study on the MIT campus. As part of the Japan program, a major bilateral workshop on barriers to scientific and technological cooperation between the United States and Japan is being planned for senior governmental, industrial, and academic figures.

The Program in Communications Policy has been in transition during the past year, following the death of its founder Professor Ithiel de Sola Pool, formerly of Political Science. Direction of the
Communications Forum, a series of seminars on both technical and policy matters, has been taken over by Professor Robert Kennedy of Electrical Engineering and Computer Science, with the assistance of Brian Kahin Esq. of the Center for International Studies. An active program of seminars has been offered for the members of the Forum from industry, the government, and the Institute. Professor Marvin Sirbu of Management has directed the core Research Program in Communications Policy for the past year; the program has continued to provide the central coordination for the cluster of educational and research activities that make up the Program in Communications Policy. Mr. Kahin has also provided support in this undertaking. Professor Russell Neuman of Political Science will take over direction of the program at the beginning of next year.

Research under the program has been active. Professor Neuman has continued work on his study on The Future of the Mass Audience. A new research facility has been constructed in Danvers, Massachusetts, which will make it possible to conduct large-scale research on audience reaction to new technologies and presentations. During the year, Dr. David Allen of the Center for International Studies completed a study evaluating the potential of business and home use of videotext; and Dr. Richard Solomon completed a collection of archival videotapes with men and women who pioneered in the development of the computer.

Professor Willard Johnson of Political Science, carried on in collaboration with the African American Issues Center of Boston University, a series of collaborative studies with African scholars on communications policy issues of common interest to the United States and the respective African country. Professor Chindji Kouleu, University of Yaoundo, Cameroon, visited the Institute to prepare a study of alternative strategies for rural communications in Cameroon. Professor Johnson and Professor Kouleu presented the results of the research to a regional conference of African scholars and officials in Cameroon.

The past year marked the 25th anniversary of the Joint MIT-Harvard Political Development Seminar, which was created by the MIT Center for International Studies and the Harvard Center for International Affairs as a forum for the presentation of research in the field of political development. During the past year, papers were commissioned to see how the assumptions of 1960 stood the test of experience and research. Professor Myron Weiner of Political Science and Professor Samuel Huntington of the Harvard Center for International Affairs are preparing the papers and discussion for publication. Also, Professor Lucian Pye completed editing the papers prepared for his study of modernization in different Asian societies.

Professors Weiner and Nazli Choucri, Political Science, developed a comparative study of steps taken by governments in the Middle East and in South Asia to regulate migration. Dr. Ahmad El-Ahmad of the Royal Scientific Society of Jordan completed a study on the economic impact of migrant labor in Jordan. Also the Center cosponsored with the Population Center at Harvard seminars on international population issues. Professor Weiner and Professor Oded Stark of Harvard University organized the seminars.

For several years, the Center has analyzed the management of risks to health and safety. During the past year, Professor Daniel Metlay of Political Science studied strategies for using scientific information adopted by groups engaged in the regulatory process. Also during the past year a final volume of papers was published as a result of work begun several years ago on the environment: Visions of Apocalypse: End or Rebirth? edited by Professor Saul Friedlander of the Hebrew University of Jerusalem, Professor Gerald Holton of Harvard University, Professor Leo Marx of the MIT Science, Technology, and Society Program, and Professor Skolnikoff.

The International Food and Nutrition Program (IFNP), headed by Institute Professor Nevin Scrimshaw, continued to be sponsored by the Center. Professor Scrimshaw has undertaken acting directorship of the Development Studies Division of the United Nations University. The Center has also continued to cosponsor with the Harvard Institute for International Development the Women in International Development group, which provides a focus of activity for faculty and students from area universities. Professor Peter Smith of Political Science has been developing a program of Latin American research and teaching. The Center cosponsored a conference on the computer in Brazil. Professor Khoury has organized seminars on issues in the Middle East. In addition, the Center has sponsored seminars on South Asia, jointly with Boston University, and on Africa. In addition, many seminars relating to other areas of Center work and to international developments generally are offered.

As in the past, the Center has had in residence scholars from other universities. This year our visitors have come from Jordan, Israel, the Peoples' Republic of China, Canada, Cameroon, as well as several American universities.
Women's Studies Program

Curriculum

One year ago, Women's Studies at MIT consisted of a loose confederation of faculty who offered six subjects in three sections of the Humanities Department during the course of an academic year, with a total annual enrollment of about 90 students. This year 11 subjects in Women's Studies were available at MIT, through the cooperation and planning of the 19 member faculty steering committee, and the annual enrollment was well over 200 students. Most subjects attracted an average of 15 students, but the notable exception was SP 431J New Women's Voices, taught by Isabelle de Courtivron and Margery Resnick, which drew 75 students. Next year 14 subjects are being offered, in Literature, History, Psychology, Philosophy, Foreign Literature, Anthropology, Science, Technology and Society, the Writing Program, and the Sloan School. Next year's new offerings reflect the variety and vitality of Women's Studies scholarship at MIT. Of the 14 subjects being offered in 1985-86, seven will be new offerings in their own disciplines as well as in Women's Studies, including SP 480J Women and Computers, SP 460/461J Psychology of Gender, and SP 482/483J Gender and Science.

In its first year the core Women's Studies subject, SP 401 Introduction to Women's Studies was taught by Margaret Andersen, Director of Women's Studies at the University of Delaware. Twenty-eight students were enrolled; about half of the students were seniors and all but three were women. Next year and hereafter it will be taught on a rotating basis by Women's Studies faculty members.

The program now has 12 concentrators and two majors. Those concentrating in Women's Studies are majors, without exception, in science and engineering fields.

The Research Room has nearly 1,000 volumes in its core collection of the new scholarship on women, and is being increasingly used by the MIT community. The Women's Studies Program has already had a significant effect on encouraging intellectual explorations of the influence of gender, race, and class on the construction of knowledge in the academy.

This year an Advisory Committee for the Women's Studies Program was appointed by Dean Friedlaender and met for the first time. The six members of the committee are drawn from four Schools: Professor Arthur Smith, Engineering; Professor Nancy Hopkins, Science; Professor Karen Polenske, Architecture; and Professor Don Blackmer, chair, Professor Heather Lechtman, and Professor Merritt Roe Smith, from the School of Humanities and Social Science.

Project Athena agreed to fund our proposal to develop a computer-based exercise in identifying gender bias in the user. Two Undergraduate Research Opportunities Program (UROP) students are developing the project over the summer, with the intention of eventually making the exercise available to all Athena users.

Publications

The faculty in Women's Studies maintained an active publications record throughout the year, including the director, Ruth Perry, who published two books this academic year (Mothering the Mind, Holmes and Meier; and a modern edition of Memoirs of Several Ladies of Great Britain, by George Ballard, Wayne State University Press [1752]), and saw another into production ("The Life and Times of Mary Astell," University of Chicago Press, 1986). Professor Sherry Turkle (The Second Self: Computers and the Human Spirit, Simon and Schuster, 1984) was named Woman of the Year by Ms. magazine. Professor Evelyn Fox Keller published Reflections on Gender and Science with Yale University Press.

Articles about the program and its faculty appeared in Tech Talk, Technology Review, the Boston Globe, the Boston Phoenix, and the Cambridge Chronicle. The program itself also produced a calendar publication called Women's Studies Around Boston, which lists area lectures and events of special interest to women's studies faculty and students.
Programming and Special Events

The year's programming began in September with a special series of opening lectures and festivities that were attended by a total of 1,500 people. Two keynote speeches were delivered by Dr. Shirley Malcom (Office of Opportunities in Science, AAAS) and Dr. Evelyn Fox Keller (Northeastern University). President Paul Gray welcomed Women's Studies to MIT and introduced faculty to the priorities of Women's Studies in technology and science education. Other special events during the program's opening week included a fiber arts exhibit featuring Boston-area women artists (funded with a grant from the Council for the Arts at MIT), an opening reception in the Women's Studies Research Room that included a reading by Grace Paley, and an afternoon outdoor concert by the all-women band, "Girls Night Out."

The Women's Studies Program also cooperated with other programs and departments at MIT on a number of events. In February, the program cosponsored a reading by Nikki Giovanni with the Black Student Union in honor of Black History Month (capacity 500+ crowd). In March and April, the program cosponsored a lecture by Tatiana Mamonova on feminism in the Soviet Union and a film by Marlan Abramowitz, As If It Were Yesterday, with the Foreign Languages and Literature faculty (the latter was covered by WBZ-TV); and cosponsored a lecture by Phyllis Mack on women and religion in early modern Europe, with the History faculty. Throughout the spring, the program cosponsored the lecture series on computers and society with the Technology and Culture Seminar. During Independent Activities Period (IAP), the program sponsored an international folk-sing of women's experiences, and facilitated the work of 20 students who met to read and discuss a variety of articles on the intellectual and legal issues pertaining to pornography. The activities of that study group culminated in a controversial showing of the documentary, Not a Love Story, that drew a capacity 450+ crowd.

In addition to these MIT events, the Women's Studies Program was awarded a $40,000 grant from the National Science Foundation to initiate a national research agenda to explore the impact of computer-communications technologies on women's changing role in society. A two-part workshop involving over 100 people began in November with a retreat at Endicott House which resulted in a day of public programming in May at MIT. Participants from around the country represented IBM, Digital, Wang Laboratories, AT&T Bell Laboratories, Xerox Corporation, and collaborated with social scientists, public policy makers, and women's studies scholars in order to encourage research on women as both developers and users of computer technology. Signs is currently considering publishing the papers from the workshop in a special issue on women and computers.

Conclusion

The Women's Studies Program has shown an increasing ability to interest the MIT community in issues of gender and society. Opportunities to collaborate with departments around the Institute, developing new subjects and cosponsoring special events, continue to grow as both faculty and students become more aware of the potential for intellectual growth in this interdisciplinary and demanding new field of academic research. We believe that the program also has high visibility in the Boston area, and is rapidly assuming a leading role in the larger academic, feminist community.

RUTH PERRY
Sloan School of Management

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 1984-85 year.

TEACHING PROGRAMS

Undergraduate Program

In the fall of 1984 the Sloan School initiated its new undergraduate program. The program, which leads to the SB degree in Management Science, contains roughly the same core of management subjects required in our previous curriculum. In addition, it contains an introduction to management science and subjects in quantitative analysis that are appropriately rigorous for the study of management science. Each student also takes four specified subjects within one of the following options: Information Systems, Operations Research, Marketing Research, or Behavioral Science. (The Class of 1985 did, and the Class of 1986 will, complete our previous curriculum.)

The emphasis on management science and the more quantitative orientation of the new program is intended to match more closely the strengths and needs of MIT undergraduates. The option in information systems is expected to provide a significant new path permitting students to study computer technology and applications without having to major in Electrical Engineering and Computer Science. It may also help ease some of the current problems caused by the heavy enrollments in Course VI.

As the following table shows, the new program appears to have produced a significant increase in sophomore enrollment in Course XV. Thirty-three sophomores entered the new program in the fall, which is more than double the sophomore enrollment in any of the previous three years. Freshman designations for next fall (19) are approximately the same as those made last spring for this fall (20).
Based on responses to a questionnaire used at the freshman open houses, we expect that a majority of our current sophomores will choose the Information Systems option. (The choice will be made during the junior year.)

Total enrollment in Course XV (old and new programs combined) for the 1984-85 academic year was 83. During the year, 23 students received the degree of Bachelor of Science in Management. Seven of these degrees were from the (old) Management Science program, three from the Behavioral Science program, one from the Dynamics of Management Systems program, and 12 from the following approved Special Programs: Information Systems (four), Finance (two), Applied Economics (two), Industrial Relations, Marketing, Corporate Strategy, and Public Sector Management.

Four of our graduates also received bachelor's degrees from departments in the School of Engineering. Two also received bachelor's degrees from the Department of Political Science. One of our graduates simultaneously received a master's degree in Management.

Enrollments for each year are summarized as follows:

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<tr>
<th>Class of</th>
<th>Designated Course XV as Freshmen</th>
<th>ENTRERED COURSE XV AS SOPHOMORES</th>
<th>Graduating Seniors</th>
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<tbody>
<tr>
<td>1984</td>
<td>10</td>
<td>14</td>
<td>29</td>
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<td>1985</td>
<td>8</td>
<td>11</td>
<td>23</td>
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<td>1986</td>
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<td>1988</td>
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SOPHOMORE ENROLLMENT

A significant—and steadily growing—number of students from other MIT degree programs are taking our undergraduate subjects. During the past year there were 436 subject enrollments by non-Course XV students. This is a 20 percent increase over 1983-84 enrollment, which was in turn 20 percent greater than enrollment in 1982-83. This year's non-Course XV enrollments represent the classroom equivalent of 50 additional full-time undergraduates.

The Sloan School's program during the January Independent Activities Period (IAP) was even more successful this year than last. For the third year in a row, there were significant increases in the number of faculty participating and the number of students attending. Twenty-four percent of our faculty participated in IAP this year, up from 16 percent last year and 11 percent the year before. This represents a doubling of faculty participation over the two-year period. Our most popular offering for the third year in a row

* The IAP Office published this figure as 12 percent last year; they did not count participating faculty whose names were not listed in the IAP Guide.
was the five-session series, "A Brief Introduction to Management," this year featuring Professors Howard W. Johnson, Stewart C. Myers, Thomas L. Magnanti, and John C. Henderson and Sloan School alumnus Steven Wallman. Average daily attendance for this series was 140, comprising mostly people from other parts of MIT. Professor Johnson's talk was, as anticipated, quite popular, drawing an audience of 225. In order to accommodate the expected overflow from Bowen Hall, we arranged for live, large-screen television coverage in the Schell Room. (This experiment was so successful that the Sloan School has since laid permanent cabling between the two rooms, making this procedure readily available for future popular events here.)

The Undergraduate Management Game was offered for the fourth time during IAP with 37 students participating (a record high). Seventeen of these students were Course XV undergraduates and six of the remaining 20 plan to receive a second SB degree from Course XV. For the first time, three units of academic credit (pass/fail) were offered to participating students.

The undergraduate program was chaired by Dr. Jeffrey A. Meldman, with Esther Merrill serving as program coordinator. Professors Thomas J. Allen, Stan N. Finkelstein, Stephen C. Graves, Peter M. Senge, and M. Anthony Wong served as undergraduate advisors, together with Dr. Meldman and Ms. Merrill. Professor Leigh McAlister served as the Sloan School's coordinator for MIT's Undergraduate Research Opportunities Program (UROP).

Master's Program

The Master's Program Committee recommended to the Sloan School faculty a revised master's core curriculum which was adopted enthusiastically in November 1984. The "new" core which is to take effect beginning fall 1985 enlarges the number of disciplines and applications in the core, while keeping its size, relative to the total master's program, constant. To achieve that, approximately half of the core subjects will now be taught in a half-semester format, meeting three times a week for an hour and a half rather than the standard two times a week. The "new" core is as follows:

15.011 Applied Economics I (Micro)
15.012 Applied Economics II (Macro and International)
15.515 Accounting and Finance I (Accounting and Control)
15.410 Accounting and Finance II (Financial Management)
15.280 Communication for Managers
15.311 Managerial Behavior in Organizations
15.660 Industrial Relations and Human Resource Management
15.930 Strategic Management
15.560 Decision Support Systems I (Information Systems)
15.061 Decision Support Systems II (Statistics)
15.062 Decision Support Systems III (Decision Models)
15.760 Introduction to Operations Management
15.810 Introduction to Marketing Management

We intend to capture in this revised core the concepts essential to understanding the rapidly changing environment in which managers operate, in order to prepare our students for leadership roles in an increasingly complex world.

The Distinguished Speakers Series enjoyed another highly successful year, drawing unusually large and enthusiastic audiences. The speakers, who were chosen by a board of master's students, were Frank Borman, Chairman, President, and Chief Executive Officer, Eastern Air Lines Inc.; William R. Hambrecht, President and Chief Executive Officer, Hambrecht & Quist; Dean LeBaron, President, Batterymarch Financial Management; Akio Morita, Chairman and Chief Executive Officer, Sony Corporation; and John Sculley, President and Chief Executive Officer, Apple Computer, Inc.

Special awards for academic excellence and professional promise were bestowed on three of our first-year master's students this year. James M. Battaglia and Paul M. Raphael received the Howard J. Samuels Memorial Fellowship and the Alexander Proudfoot Company Fellowship, respectively, which are made possible through annual gifts from the Alexander Proudfoot Company. The Digital Equipment Corporation selected Barbara A. Gee as recipient of its annual scholarship intended to encourage women to pursue management careers in the high technology industry.

Several second-year master's students also won scholarships in recognition of exceptional academic achievement and professional promise. Raymond F. Clarke was named Henry Ford II Scholar for 1984-85; the funds for this annual award were originally provided by a gift from the Ford Motor Company Fund.
The Henry B. du Pont Scholars were Om P. Chokriwala and Katherine T. McLeod; these scholarships were established by the Crestlea Foundation with a gift from the late Henry B. du Pont. The first recipients of Martin Trust Scholarships, recently established by Martin Trust, a graduate of the master's program, were Mary F. Christ and Andrew D. Lawrence. Robert L. Clyatt and C. Michael Iles were named Seley Scholars, annual awards established by Mr. and Mrs. Louis E. Seley. Receiving the Thomas M. Hill Prize for a second-year student demonstrating excellence in the field of accounting was S. Robert Chad; this annually awarded prize was established by the late Professor Hill's friends and colleagues to honor his memory and distinguished service to the School for 30 years.

Graduating students Robert L. Clyatt, Andrew D. Lawrence, and Jeffrey B. Magill were honored with William L. Stewart, Jr., Awards, which are presented each year at the Institute's Awards Convocation to students "who have made outstanding contributions to extracurricular life at MIT." Messrs. Clyatt, Lawrence, and Magill were cited for their founding and continuing leadership of the Sloan Volunteer Consulting Group.

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. The winner for the 1983-84 academic year was Philip N. Duff, whose thesis is entitled "Antitakeover Defensive Tactics: Theory, Practice, and the Effects on Stockholder Wealth." His thesis supervisor was Professor Richard S. Ruback. Receiving honorable mention was Anthony M. Saponaro, whose thesis is entitled "Is the Red Line Really That Bad? An Assessment of the Actual and Perceived Service Provided by the MBTA's Red Line." Professor Arnold I. Barnett was his thesis supervisor.

Not only did we experience an increase in the number of applications for admission this year, but several application readers commented on the exceptional quality of the candidates as well. For example, the average undergraduate grade-point average for the full pool of 1,400 applications was 4.3 (out of 5.0), and the median GMAT score was 630 (93rd percentile). For the third time we selected an entering class of 200 students.

The following table presents a profile of the graduating classes of 1985 and 1986.

<table>
<thead>
<tr>
<th>Profile of Graduating Master's Classes</th>
<th>1985</th>
<th>1986*</th>
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<tbody>
<tr>
<td>Number of Candidates</td>
<td>193</td>
<td>192</td>
</tr>
<tr>
<td>US Citizens</td>
<td>137</td>
<td>140</td>
</tr>
<tr>
<td>Foreign Citizens</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>Women</td>
<td>52</td>
<td>43</td>
</tr>
<tr>
<td>Members of Minority Groups</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Median GMAT Score (national average is approximately 460)</td>
<td>650</td>
<td>640</td>
</tr>
<tr>
<td>Undergraduate Grade-Point Average (out of 5.0)</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Undergraduate Majors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humanities</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>33%</td>
<td>28%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>16%</td>
<td>15%</td>
</tr>
<tr>
<td>Engineering</td>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>Pre-Professional</td>
<td>14%</td>
<td>18%</td>
</tr>
<tr>
<td>Average Years Full-Time Work Experience</td>
<td>3.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Age at Admission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 23 years</td>
<td>19%</td>
<td>15%</td>
</tr>
<tr>
<td>23-24</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>25-26</td>
<td>18%</td>
<td>21%</td>
</tr>
<tr>
<td>27-28</td>
<td>14%</td>
<td>16%</td>
</tr>
<tr>
<td>29 and over</td>
<td>19%</td>
<td>18%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geographical Areas Represented</th>
<th>Home</th>
<th>College</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England</td>
<td>28%</td>
<td>36%</td>
</tr>
<tr>
<td>Mid-Atlantic States</td>
<td>20%</td>
<td>17%</td>
</tr>
<tr>
<td>South and Southeast</td>
<td>6%</td>
<td>4%</td>
</tr>
</tbody>
</table>
Members of the SM Class of 1985 received a warm welcome in the job market this year. Pre-recruiting events began early in the fall, reflecting employers' optimism about the season ahead. A record number of companies scheduled presentations to master's candidates, and student clubs attracted an impressive roster of speakers wishing to inform individuals about work opportunities in a variety of fields. This high level of hiring-related activity continued through March.

By the end of on-campus recruiting, the Placement Office had hosted 141 interviewing companies, down slightly from 148 firms in 1984. The economic downturn in several areas of the electronic industry accounted for the decrease.

Despite disappointments for students interested in the computer and semiconductor fields, the overall job market for the graduating class was healthy. On average, students each received three job offers at salaries about 9 percent above last year's figures. Starting salaries reported to date indicate a class mean of $42,400. This means a favorable return on investment for Sloan students who earned an average salary of $25,300 prior to entering their SM program.

Approximately 40 percent of the master's graduates did not take their highest offer. Although financial considerations were certainly important, when asked about factors influencing their final choice of positions, students noted that the opportunity to work in their preferred job functions was their number one consideration. The people with whom graduates would work and the opportunities for professional advancement were also specified as key variables driving career decisions.

A review of the job functions selected by 1985 graduates shows a sharp increase this year in individuals entering consulting roles; 27 percent of the class chose the consulting function, compared with 14 percent in 1984. The other popular job functions were finance (20 percent of the class), followed by marketing (18 percent) and then management information systems (10 percent). In terms of industrial affiliation, the picture remains similar to last year's, with consulting leading by a significant margin. Electronics equipment manufacturers hired the next largest percentage of graduates (19 percent), followed by commercial and investment banking (10 percent and 9 percent, respectively). Seventy percent of the Class of 1985 entered the service sector, while 30 percent selected manufacturing organizations.

Employers hiring three or more SM graduates this year included Booz, Allen & Hamilton Inc.; Chemical Bank; Citicorp; Credit Suisse First Boston; Hewlett-Packard Company; IBM; and McKinsey & Company, Inc.

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 new subjects allowing intensive study of the management of technical people and programs. Subjects in Managing Professionals, Marketing/Technology Interface, Manufacturing/Technology Interface, and Current Issues in Engineering 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 Program Director, Professor Edward B. Roberts, of the Sloan School. Admissions and daily operations are ably handled by Jane M. Morse, Program Manager, who has been with the program since its beginning. From a pilot class three years ago of six students, the program expanded to eight the next year, 13 the year after, and 20 students for the just-completed 1984-85 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.

Program implementation would not have been possible without the strong and effective collaboration of the Deans' Offices in both the School of Engineering and the Sloan School of Management. Substantial financial contributions to fund curriculum development from Pilkington Brothers Ltd. and Gillette Company are also greatly appreciated, as are gifts from Corning Glass Works, Rogers Corporation, and Computer Services Corporation (Japan).

The PhD Program

The Sloan School's doctoral program, which remains one of the most distinguished in the nation, experienced another successful year in recruiting an incoming class of highly qualified men and women. A total of 259 applications was received for fall 1984, an increase of 8.8 percent over the previous year. Admission was offered to 32 applicants, and 15 entered the program in September. The yield rate (entrants/admissions) of 47 percent was slightly below those realized over the past decade. The entering class included two women and nine citizens of foreign countries. The major fields chosen by the 1984 entering class were as follows:

<table>
<thead>
<tr>
<th>Field</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Economics and Finance</td>
<td>0</td>
</tr>
<tr>
<td>Applied Economics</td>
<td>0</td>
</tr>
<tr>
<td>Finance</td>
<td>0</td>
</tr>
<tr>
<td>Behavioral and Policy Sciences</td>
<td>9</td>
</tr>
<tr>
<td>International Management</td>
<td>2</td>
</tr>
<tr>
<td>Industrial Relations</td>
<td>1</td>
</tr>
<tr>
<td>Organization Studies</td>
<td>5</td>
</tr>
<tr>
<td>System Dynamics</td>
<td>1</td>
</tr>
<tr>
<td>Management Sciences</td>
<td>6</td>
</tr>
<tr>
<td>Management Information Systems</td>
<td>3</td>
</tr>
<tr>
<td>Marketing</td>
<td>2</td>
</tr>
<tr>
<td>Operations Research</td>
<td>1</td>
</tr>
</tbody>
</table>

The proportion of foreign applicants continues to grow. The foreign share of all applicants has increased from 40 percent in 1970 to 65 percent in 1984. This shift has been reported by most other leading US management schools. We continue to cooperate with the efforts of the American Assembly of Collegiate Schools of Business (AACSB) to recruit more qualified US applicants, and we plan to increase our own efforts substantially in coming years.

The bulk of the program's graduates pursue academic careers. In 1984-85, 13 doctorates were granted in Management. Of these, eight (62 percent) are pursuing academic careers at Harvard, MIT, Berkeley, Wharton, and Korea. The remaining five have accepted or are considering non-university positions.

The Doctoral Program Committee, headed by Professor Richard Schmalensee, has grappled with a number of difficult and interrelated problems. In recent years, the median time taken to complete the program has begun to creep above four years. After considerable study and debate, a number of changes were made in the program's pre-dissertation research requirements in order to facilitate more rapid progress. Maintaining the long-established size of the program (ideally, about 20 new students each year) without sacrificing quality has proven difficult in the face of stiffening competition from other management schools, even though demand for PhDs to staff management schools here and abroad continues to outstrip the available supply. Our main rivals are able to offer more attractive and longer-term financial awards to the most attractive applicants, and the aggregate supply of qualified US applicants has not responded to the excellent career prospects for management PhDs. Fellowship funding for the program was significantly increased this year in order to meet these challenges; for the first time in some years we will be able to make financial awards that are not grossly less attractive than those made by our principal rivals.

Administration of the doctoral program continues to be handled with great effectiveness by Sharon Cayley.
Alfred P. Sloan Fellows Program

On June 3, 1985, 57 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1985 was the largest in the history of the program. It 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 54th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Europe. They visited with leading government and industrial representatives in Spain, Hungary, USSR, and France.

A comparison of the Class of 1984-85 with previous classes follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>76-77</th>
<th>77-78</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>
</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>25</td>
<td>26</td>
<td>31</td>
<td>30</td>
<td>31</td>
<td>30</td>
<td>28</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>International</td>
<td>11</td>
<td>14</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>15</td>
<td>13</td>
<td>15</td>
<td>13</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>8</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>10</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>International</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</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>1</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>1</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>Medical Management</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3*</td>
</tr>
<tr>
<td>Church Management</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</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>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Foreign</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>54</td>
<td>55</td>
<td>54</td>
<td>56</td>
<td>56</td>
<td>55</td>
<td>55</td>
<td>56</td>
<td>57*</td>
<td></td>
</tr>
</tbody>
</table>

* Medical Management Sloan Fellows also counted in US Government and Government-International category.

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 14, 1985, the Class of 1985-86 arrived; there are 55 participants in the 1985-86 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 Arnoldo C. Hax served as chairman of the faculty program committee.

Health Management Executive Development Program

The 10th year of operations was completed by the Health Management Executive Program as an integral part of the Alfred P. Sloan Fellows Program. There were three Sloan Fellows from the medical field: Margaret E. Dickerman, Chief Social Worker--Inpatient Child Psychiatry, New England Memorial Hospital; Robert G. Hartling, Branch Chief--Systems Analysis and Programming, Academy of Health Sciences, Department of the Army; and Benjamin Z. Kallner, MD, Medical Officer, Israel Defense Forces Medical Corps.

Program for Senior Executives

During 1984-85 the number of participants in the program increased to 96. The program continues to attract outstanding senior executives from private and public organizations around the world, with a growing participation from Pacific basin countries.

In December 1984, Dr. H. Scott Duncan resigned as Director and Dr. Edwin C. Nevis was appointed Director. Dr. Nevis was a member of the core faculty of the program since 1979. Professor Henry D. Jacoby succeeded Professor Michael S. Scott Morton as Chairman of the Faculty Committee.
Greater Boston Executive Program

Continuing to serve as an important link between MIT and the Boston area business community, the Greater Boston Executive Program enrolled 19 participants in the 1985 session held from January 25 to May 3.

The executives, 15 men and four women, met each Friday for 15 weeks for sessions on economics, finance, accounting and control, human resources management, marketing, and strategic planning offered by the Sloan School faculty.

Summer Programs

During the 1984 Summer Session, Sloan School faculty participated in 12 Special Summer Programs.

Two of the programs were of two-week duration: Corporate and Economic Policy Design with Microcomputers: A System Dynamics Approach, co-directed by Professor John Sterman and Mr. David Kreutzer of the System Dynamics Group; and Management of Research, Development, and Technology-Based Innovation, under the direction of Professor Roberts.

The rest of the programs were one-week offerings. In the health-care area, Professor Roberts chaired The Dynamics of Health Service Systems: Strategic Planning for Complex Health Organizations; and Professor Finkelstein directed Management of Medical Technology: Development, Utilization, and Cost.

Strategic Planning Systems was offered by Professor Hax, assisted by Professor Scott Morton and Walker Lewis, founder and president of Strategic Planning Associates. Professor Hax and Professor Gabriel R. Bitran also assisted Dr. Harlan C. Meal, who directed The New Production Planning. Dr. J. Morrison McKines chaired the group offering Corporate Planning and Control Systems. Professors John J. Donovan and Stuart E. Madnick again offered Critical Information System Technologies: Managing in the Information Era. Professor Jeremy F. Shapiro, who is also Co-Director of the Operations Research Center, directed Resource Management: A New Approach to Corporate Planning.

In a change of format, Professor Myers, assisted by other members of the finance faculty, offered Modern Concepts in Financial Management as a one-week, live-in program at the new facilities at MIT's Endicott House and Conference Center in Dedham. This proved extremely successful and there are plans to hold other sessions at the Center in the summer of 1985.

Two new programs were offered. Professors Henderson and Michael E. Treacy directed Decision Support Systems and the Management of End User Computing, which attracted a large audience, and Professor Bitran assisted in the development and presentation of Operations Management in the Services Industries, which was directed by Richard C. Larson, Professor of Electrical Engineering and Computer Science and Co-Director of the Operations Research Center.

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 ninth annual summer seminar at the Hyatt Regency in Cambridge. The topic was "Current Issues in Information Systems: Managing in the Information and Communications Era." The Marketing Center held its 17th annual symposium in May. This was a three-day seminar on Marketing Strategy in the Information Age. All sessions were held at MIT's Endicott House.

Industrial Liaison Symposia

Sloan School faculty also chaired or participated in several of the Industrial Liaison symposia held during the year. In November Professor Roberts was responsible for a program on Management of Research, Development and Technology-Based Innovation held in Houston, Texas. Professor Jay W. Forrester chaired a program at Kresge in January on Systems Thinking and the Design of Corporate and Economic Policy.

During the spring a program on Managing the Transition to the Fifth Generation was co-sponsored by the Industrial Liaison Office, Digital Equipment Corporation, and the Sloan School. Sloan School participants were Professor Scott Morton and Richard Beckhard, who retired as adjunct professor last year.

The Industrial Liaison Office also sponsored a few short courses at different European locations and two of these were directed by Sloan faculty. During January Professor Hax directed a three-day course on Corporate Strategy in Paris, France, and Professor Roberts was responsible for another short course on Management of Research, Development and Technology-Based Innovation in Stockholm, Sweden.

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: Behavioral and Policy Sciences; Economics, Finance and Accounting; and the Management 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.

Behavioral and Policy Sciences

The Behavioral and Policy Sciences Area deals with a broad range of managerial issues ranging from context specific subjects like international management, technology and innovation, and human resource management through process activities such as strategy and policy and on into the disciplinary foundations of management, including organizational studies and decision-making behavior. Throughout this diversity run certain important commonalities, especially the themes contained in the name of the area: the research methodologies of the behavioral sciences and, from various perspectives, a continuing concern for policy issues.

The area seeks to cultivate multi-disciplinary research and the past year saw the startup of a significant new, School-wide project, "Management in the 1990's," directed by Professor Scott Morton of the strategy and policy subgroup. The project is a five-year, 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 impacted by the new information technologies. The research team draws from across the School and includes individuals from strategy and policy, organization studies, industrial relations, international management, technology and innovation, and information systems.

Classifying the faculty's research involves 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 interconnections.

Human Factors in Management. Not only are human issues central to the management of an organization, but they are 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.

In Organization Studies the faculty are concerned with understanding the relation between the individual and the organization and the dynamics of behavior in organizations. Professor Edgar H. Schein this year completed a book on organizational culture, an important topic that has stirred much interest in recent years. He has also become interested in the assumptions underlying the methodology of clinical research and how it differs from ethnographic and other field methods. A paper on the subject has been written and will appear in the final report volume of the group's Office of Naval Research project, conducted with Professor John E. Van Maanen and Professor Lotte Bailyn.

Professor Van Maanen has been writing about comparative socialization practices, ritual and group membership, uses of power and authority, and occupational and organizational culture. A good portion of this work has been done in the context of police organizations, and during his sabbatical leave in 1983-84, he had a unique opportunity to conduct field work with the Metropolitan Police Department in London, which provided a rich, new source of data for his research.

The managing of technical careers has been an ongoing focus of Professor Bailyn's research. She has written this year on career progression in R&D as well as on various methodological issues arising in such research. She is now at work on a volume summarizing an accumulation of her work on careers. She is also embarking on a new comparative study of men and women in technical careers to determine how work relates to family, personal orientations, and occurrence of burnout.

Professor John S. Carroll and Professor Max Bazerman are studying judgment and decision-making behavior. In particular they are investigating how negotiators think about negotiation tasks, with a specific concern for the ability to understand an opponent's cognitions. This work will be supported by the National Science Foundation's Decision and Management Sciences Program starting next year. As part of the Sloan School's Management in the 1990's Project, Professor Carroll is also studying the introduction of microcomputers in large corporations. His concern is with the impact of expectations on implementation strategy and process.

Among the research activities of Professor David G. Anderson has been the study of corporate revitalization: how large companies plan and implement major changes in strategy, organization, and culture. This work has been extended this year with the addition of three intensive case studies conducted by Sloan Fellows. In another area he has preliminary findings that support the proposition that innovative products in the electronic instrument industry are best understood as aggregations of many small steps, called micro-innovations. Professor Walter W. Powell, considering the limitations of large-scale organization, seeks to account for the proliferation of mixed modes (neither market nor hierarchy) of organization. Once his theory has been developed the next step will be testing.
In the other part of the Behavioral and Policy Sciences Area that specializes in human issues, the Employment and Industrial Relations subgroup is in the final phase of the Sloan Foundation project on "U.S. Industrial Relations in Transition." Two books were published this year: Professor Thomas A. Kochan edited a volume on challenges and choices facing American labor; and he, Professorary C. Katz, and Nancy Mower were authors of the second on worker participation and American unions. A final volume, summarizing the project, is underway, coauthored by Professors Kochan, Katz, and Robert H. McKersie. Professor Kochan and Dr. Thomas A. Barocci also completed and published their textbook on human resource management and industrial relations. Professor Katz's book on changing labor relations in the US automobile industry, which was part of the MIT Future of the Automobile project, also appeared this year.

A major upcoming research thrust of the group is human resource management. Both Professors Kochan and McKersie have presented initial papers on aspects of this topic. In different but related work, Professor Katharine G. Abraham has been investigating the factors that determine earnings across broad occupational groups. She finds that blue-collar earnings vary significantly depending on whether the individual is in a long-duration job or a short one. White-collar earnings, on the other hand, do not.

It is a pleasure to note that Professor Kochan received the first annual Willobee Abner Award for Research in Dispute Resolution. This recognized his past contributions in mediation, fact-finding, and interest arbitration in the public sector.

The 10-year study of five Sloan School classes (1975-79) by Professor Phyllis A. Wallace is now in the data analysis stage and beginning to yield important findings. Approximately 360 individuals were tracked for five years after graduation. One of the preliminary results, now being confirmed, is that five years after graduation Sloan women who are full-time employees appear to do as well as their male counterparts.

Professor Bazerman has been focusing on the theoretical and empirical analysis of human judgment in situations, such as negotiation and arbitration, that have competitive aspects. A current thrust in this work is part of the Management in the 1990's Project, where he is studying service-based organizations (e.g., consulting firms) in their task of negotiating transactions with clients.

System Dynamics. Over the past several years research has focused on the System Dynamics National Model of economic behavior. The model itself is now substantially complete and attention is turning to a series of books that will describe the model and the insights that have come out of it. One aspect that has drawn a good deal of discussion is an integrated theory for explaining an economic long wave of 50 to 75 years' duration. Much of the work on the national model has been conducted by Professors Forrester, Senge, and John D. Sterman, and Research Associate Alan Graham.

Professor Sterman has further analyzed the long wave, building a simplified model of it that can be studied separately from the National Model and examining empirical support for the phenomenon. A participatory simulation game has also been built and used in a variety of settings to illustrate the principal dynamic processes hypothesized for the long wave. He has also been active in identifying methods for evaluating forecasting methods when repeated comparison of forecasts and outcomes is impossible.

Another major thrust in system dynamics lies in the corporate policy area. A relatively few building-block models, referred to as generic structures, can provide a tool kit for understanding a wide variety of policy issues. Professor John D. W. Morecroft has worked on this and also gone a step further to develop a framework that combines system dynamics with concepts from organization theory and behavioral decision theory into a flexible yet powerful tool for business policy research. He is testing this framework in the field.

Management of Technology. Increasingly competitive international markets and a large trade deficit have turned national attention to 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 take on increased importance both for the firm and the economy. Professor Eric von Hippel has completed a book on this, emphasizing the role of users in the innovation process, and how innovators capture the benefits of their efforts. In work with Professor Glen L. Urban of the marketing group, Professor von Hippel is also studying the idea of employing 'lead users' to improve the ability of market research to generate and evaluate radical new product concepts.

Professor Allen has embarked on a major new study, under the sponsorship of the Management in the 1990's Project, in which the communication patterns of 750 software engineers will be monitored for a period of 18 months while their communication capabilities via personal computer work stations and networks are gradually improved. At the same time he continues his work on international technology transfer, following technical and managerial employees who leave large multinational firms to go into small local manufacturing companies. Professor Roberts continues his research into product line strategies of small high-technology firms and into the formation and growth of new biomedical enterprises. Also as mentioned earlier, Professor Anderson is doing research on micro-innovation.
Strategy and Policy. Domestic and international competition in the business world has heightened in recent years, causing 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 gravitated 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 Hax has done a great deal of work on the design and implementation of formal strategic planning systems. An important part of his effort has involved students working on master's theses doing empirical work on individual companies. During the past year, he summarized the central thrust of his work in two books, one providing his integrated perspective of strategic management, and the other a readings book on the subject. In continuing work he is seeking to link more closely the various managerial functions to the strategic planning process. Particular emphasis has been put on a methodology for articulating the manufacturing and technology interface with planning. Another step is the development of human resources strategy.

Professor Hax was honored during the year for a book he coauthored with a former doctoral student, Professor Dan Candea of Romania. Their book on production and inventory management was given the Joint Publishers-American Institute of Industrial Engineers Book-of-the-Year Award.

As described earlier, Professor Scott Morton is engaged in running the Management in the 1990's Project. Within that he has a personal research interest in the strategic opportunities opened up for non-technical firms as a result of information technology developments.

Professor Mel Horwitch has been studying large-scale enterprise with a special emphasis on the characteristics and limits of professional strategic management in attempting to deal comprehensively with the complex issues brought about by scale. He is also investigating the changing relationship between technology and strategy in technology-based industries.

The problem of managing vendors and their markets has concerned Professor Gordon Walker. He has taken the point of view of business and corporate strategy and brought in analytic methods from economics and organization theory. In a second research program he is working on organization design in information-intense organizations, approaching the problem as a task network which he operationalizes using block-modeling techniques.

Professor Zenon S. Zannetos, although his primary energies are absorbed by School resource development, continues his long-standing research on industry productivity analysis and the economics of ocean transportation.

International Management. One cannot read the daily newspaper without sensing the global forces that have brought the issues of the multinational corporation and international management into prominence. The Sloan School, as is true of the rest of MIT, has always attracted substantial numbers of non-US students and its faculty has always maintained communication with many other countries.

One of the lines of research being conducted by Professor Donald R. Lessard concerns external finance for developing countries. He finds 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 be barriers 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.

Professor Richard D. Robinson, returned from sabbatical leave of the year before, has done preliminary research on the Union Carbide accident in India and the implications arising from it, which are manifold. He is also continuing his work on international technology transfer.

In recent years the international management group has developed significant strength in Pacific rim affairs through faculty members 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 starting an environmental scanning project as part of the Management in the 1990's Project.

Professor Simon is doing research on technology transfer and the assimilation of technology into developing countries. A current study is the modernization of Shanghai's electronics industry. This research is designed to analyze how changes in China's economic climate affect the behavior of firms regarding technological innovation and foreign technology acquisition. Another project is examining the variables that determine the key sources of innovation in Chinese industry.
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. Professor Finkelstein, who directs the interdisciplinary Laboratory for Health Care Studies in Whitaker, is doing research on a variety of topics. One of his principal interests 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 makes 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.

In addition he has been working with Senior Lecturer Gordon F. Bloom to establish an organization called the Massachusetts Critical Issues Forum. This is a committee of respected leaders from industry, government, and public interest groups, who have as their objective the resolution of controversial issues through consensus supported by research. The first likely subject is the private financing of low-income housing. Another promising one is the impact on employees of visual display terminals.

Economics, Finance, and Accounting

This area was strengthened this year by the addition of the Accounting Group to the Applied Economics and Finance Groups. Research in all three groups is generally grounded in economics, but with different areas of application. Applied economics is mostly concerned with the economic environment, both domestic and international, in which the firm operates. Finance works to understand capital markets and the implications of capital markets for management and public policy. Accounting seeks to understand the flow of information from the firm's operations to its management, investors, and customers. We look forward to a productive interchange between scholars in these three areas.

Applied Economics. Professor Ernst R. Berndt was on sabbatical leave during the past academic year. He continued his research on the valuation, growth, and changing composition of the capital stock of the United States and other countries.

Professor Jacoby's research activities fell into two categories. The first is the analysis of energy and resource projects using methods of option valuations. The primary focus here has been on the evaluation of oil reservoirs under different tax regimes. Research in the second category includes a continuation of earlier work on US natural gas markets, in particular the analysis of off-shore taxation as applied to gas and the analysis of the natural gas market under conditions of soft demand and deregulation of field prices.

Professor Paul R. Krugman continued his theoretical work on international trade under imperfect competition and increasing returns to scale. He is also analyzing the implications of recent developments in these areas for trade and industrial policy. He has begun empirical work on whether the dollar's strength can be sustained in the future.

Professor Edwin Kuh continued as Director of the Center for Computational Research in Economics and Management Science. His most recent research addresses two topics: regression stability analysis and guided computing. His work on regression stability analysis should generate a significant advance in understanding how to test and find the limits of testing in regression models, especially ones subject to outliers. Guided computing concerns the application of expert system concepts to quantitative analysis, mainly regression.

Professor Robert S. Pindyck's research during the past year spanned several areas. He has continued his work on the nature of business risk in the United States, including the ways in which uncertainty about price, cost, and rates of return affect the investment, output, and pricing decisions of firms, as well as the behavior of markets. He has also been working jointly with Professor Julio J. Rotemberg to develop econometric tests to determine whether imports are the "substantial cause" of injury to a domestic industry. This test is based on data for the domestic copper industry.

In addition to his joint work with Professor Pindyck, Professor Rotemberg has worked with Professor Garth Saloner of the Economics Department to understand the consequences of implicit understandings among firms operating in oligopolistic markets. They showed that implicit understandings can be important elements in explanations of fluctuations in aggregate economic activity. He has also investigated the connection between the incidence of taxes and aggregate business activity. This work is conducted with Professor James Poterba, of the MIT Economics Department, and Professor Lawrence Summers, of the Economics Department at Harvard.
Professor Schmalensee has worked with Professor Paul Joskow of the MIT Economics Department on estimates of trends in costs and performance of electric-generating units. In addition, he completed a paper on the so-called differential efficiency hypothesis. The paper uncovered apparently sharp changes in the relative profitability of small and large firms over time. He plans to look more closely at this issue in the future.

Professor Thomas M. Stoker's research this year was based in three domains: 1) issues relating to aggregation in studies of macroeconomic and macroeconomic data; 2) aggregation and identification in macroeconomic models; and 3) interpretation of micro-level regression statistics in terms of aggregate effects. He has also developed a new class of solutions to nonparametric estimation and hypothesis testing problems based on knowledge of the distribution of predicted variables in econometric models.

Professor Thurow has directed most of his research efforts this year to a new book tentatively titled The Zero-Sum Solution: Building a World-Class Economy. He is also developing a research paper on the income distribution effects of international trade.

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Professor Ruback was on leave during the academic year on a Batterymarch Research Fellowship. He collaborated with Professor Wayne Mikkelson of the University of Oregon in investigating various issues surrounding corporate investment in other corporations' common stock. These purchases often lead to takeovers or targeted repurchases of the shares. Professors Mikkelson and Ruback have gathered new evidence on the impact of targeted repurchases on stock prices. In addition, Professor Ruback has continued research on procedures for evaluating capital investment decisions, with particular attention to the valuation of debt-equivalent cash flows.

Accounting. Professor Paul M. Healy's research interests include the relationship between executive compensation and accounting procedures and models of capital market expectations of future earnings. Empirical tests on the first topic suggest that executive compensation is significantly affected by accounting changes. The purpose of research on the second topic is to develop a model that will provide more precise forecasts of earnings than standard forecasts made by management, analysts, or statistical techniques. He is working on this project with Professor Marsh.

Professor Sudhir Krishnamurthi has completed a paper analyzing analysts' earnings estimates for small firms and is investigating the use of simulation techniques to test the predictive ability of security prices for accounting earnings. He is also working with Professor Ram Ramakrishnan on a paper investigating the link between managerial risk and rewards and to identify whether there are systematic differences in the way different industries reward managerial performance.

Dr. McInnes has worked with Professor Ramakrishnan on methods to determine the effectiveness of budgetary control systems. The data collection for this project was completed and analysis is progressing, with several papers in advanced stages of preparation. In addition, Dr. McInnes is continuing his research on corporate management of productivity.

In addition to his work with Dr. McInnes, Professor Ramakrishnan is investigating how uncertainty affects the emphasis put on budgeting systems for a performance evaluation. He is testing hypotheses derived from agency theory. Professor Ramakrishnan is also pursuing theoretical work in management accounting; for example, the analysis of cost allocation schemes under asymmetric information.

Professor H. David Sherman's extended earlier work evaluating alternative methods of improving the performance of service industries. His investigations also assessed the relative success of these approaches in applications to several government, non-profit, and business organizations. He has also completed exploratory studies of the nature of management control systems in successful new ventures, as well as the impact of venture capitalists and underwriters on the initial public offerings of emerging businesses.

Management Sciences

The challenges posed by the information and microcomputer revolution and by heightened international competition continue to stimulate much of the Management Sciences Area's research. These challenges have had a profound influence on managers, prompting them to consider 1) new opportunities for developing and using managerially relevant data and allied decision support systems; 2) the organizational impacts caused by the changing environment; and 3) the ways in which these changes affect business planning and basic managerial processes, such as production, marketing, and distribution.

The Management Sciences Area has a long-standing tradition of addressing these issues, often in collaboration with practicing decision-makers and government sponsors. Since the area's inception in the late 1960s, its research has emphasized decision support models, measurement, and information systems, and has been characterized by a balance of applications and theory. This research is enriched by the faculty's active participation in centers at the School (Marketing Center, Center for Information Systems Research) and at the Institute (Operations Research Center, Statistics Center, Center for Transportation Studies, Artificial Intelligence Laboratory). In addition, the area's faculty has expanded its collaboration beyond its traditional boundaries even further by actively participating in the School's new large-scale research program entitled Management in the 1990's, and by its efforts with the Engineering School to develop a joint research and teaching program in manufacturing.

The following brief research summary, organized by the area's four subgroups, highlights a few of the faculty's activities from this past year. Even though this research agenda is quite diverse, it is characterized by a common theme: the area's research encompasses a spectrum of contextual and methodological issues on the generation, interpretation, and use of data; on the development, calibration, and validation of models; and on behavioral issues related to implementation and the changing managerial environment.

Marketing. The Marketing Group continued to stress "Marketing Science" which is built upon careful axiomatic, modeling, measurement, and application synergies. The group's efforts focused on consumer goods. Professor John R. Hauser and Professor Urban collaborated on the design and strategic implementation of new products (including completion of an undergraduate textbook) and on the prelaunch forecasting of consumer durables. In addition, Professor Urban studied market shares for pioneering brands, and Professor Hauser worked on defensive marketing strategies and agendas and began to work on international marketing.
Professor McAllister's research emphasized marketing promotion expenditures; she has developed theoretical models of consumer response to price promotions, and empirical methods for testing these models. In her research on judgmental heuristics and processing shortcuts, Professor Deborah L. Marlin studied consumer evaluations of unfamiliar objects. In a related effort, Professor Eric Johnson, a visitor from Carnegie-Mellon University, studied cognitive issues related to consumer information processing. Professor John Little, now Head of the School's Behavioral and Policy Sciences Area, continued to build models of customer behavior and market response and to calibrate them by optical scanners at point of purchase. He also studied coupon promotions. Professor Alvin J. Silk, the School's Deputy Dean, has continued to study organizational issues related to advertising agencies, including the analysis of policies for the developing and testing of creative advertising alternatives.

Operations Management. Traditionally, the Operations Management Group has worked closely with industry to develop decision support models for a wide variety of operational planning situations. Much of the group's efforts this past year focused on manufacturing, particularly for high-technology industries. Professor Bitran, using several companies as field sites, studied a variety of production planning problems including production scheduling for semiconductors, and the manufacturing of silicon wafers and microwave conductors. He also began developing decomposition procedures for networks of queues and approximation methods for dynamic stochastic production problems. Professor Charles H. Fine continued his investigations of quality-based learning and of manufacturing strategy. He also started new research on the economics of flexible manufacturing technologies. Professor Graves and Dr. Meal continued to collaborate on production planning in dynamic production environments (with applications to integrated-circuit manufacturing) and on ways to organize production flow and to design manufacturing systems in a job shop. Professor Graves also worked on planning models for less-than-truckload shipping and for resource planning in community-based mental health care systems. Dr. Donald Rosenfield, a visitor on sabbatical from Arthur D. Little, studied a variety of issues in logistics including the design of multi-location distribution systems, facility location, and strategic aspects of logistics. During the year, he also completed a book on logistics.

Management Information Systems. The Management Information Systems Group's research is central to the many managerial planning issues raised at the outset of this research summary. The group's efforts span a broad range of behavioral, managerial, and technological concerns including organizational impacts of changing information technology, management of end-use computing, decision support and expert systems, telecommunications, and data base architectures. Working in conjunction with MIT's Artificial Intelligence Laboratory, Professor Randall Davis studied expert systems, qualitative reasoning, and knowledge-based signal processing. Part of his effort has been devoted to developing the "next generation" expert systems that replace empirical associations with an understanding of how systems work. In related work, Professor Thomas W. Malone studied expert systems for intelligent information sharing and filtering. His research aims to develop a theory of organizational science that addresses such issues as organizational impacts of information technology and computer systems based on analogies with human organizations. Dr. Charles Jonscher, drawing upon methods from economics, studied modeling of information resources and their impact on productivity. Working with Professors Henderson and Treacy, Dr. John F. Rockart continued to study the critical success factor methodology and executive support systems. He also initiated research on the management of data resources. Professor Henderson also studied the impact of technology on an organization's critical decision processes and on the use of new service-oriented measurement tools to analyze productivity of information services. Professor Treacy's research aims to develop techniques for evaluating the impacts of information technology on managerial and organizational productivity. He has developed models and measurement instruments to assess users' satisfaction with information systems and the value of end-user computing, and studied the impact of end-user computing on a firm's strategic objectives. In the technology area, Professor Madnick, in conjunction with Drs. Hoo-Min Toong and Amar Gupta, continued to study new data base architectures and a design methodology for structuring the early stages of architectural design. This past year his research emphasized formal theory and the implementation of a prototype design. Professor Marvin A. Sirbu's research focused on two major topics: computer communications standards and management of corporate telecommunications networks.

Operations Research and Statistics. The Operations Research and Statistics Group studied the underlying methods of Management Science and their application in a broad range of contextual situations including logistics, energy, public policy, manufacturing, and health care. Professor Roy S. Welsh continued to study issues in robust statistics including regression procedures that are not overly sensitive to small fractions of aberrant data. He also began work on expert systems for the study of statistical strategy. Professor Wong pursued his interests in cluster analysis, considering such methodological issues as block clustering. He also worked on a number of applications including usage of counterfeit credit cards, the structure of industrial markets, classification of viruses, and analysis of human gait. Professor Barnett's work in applied probability contributed to the analysis of criminal justice systems particularly on issues of prison sentencing. Professor Kaufman studied sampling methods for finite populations and successive estimators, and continued to study the estimation of oil and gas resources. In the area of mathematical programming, Professor Shapiro pursued his studies of integer and stochastic programming, and the applications of these methods to manufacturing, logistics, and energy planning. He also initiated new investigations on the solution of large-scale optimization problems by parallel computation. Professor Robert M. Freund studied several methodological issues in nonlinear programming and fixed points. He also began research on a new algorithm for linear programming, and on applications of mathematical programming in flexible manufacturing and on the economics of depletable resources. Professor James B. Orlin developed
new algorithms, with improved guaranteed performance, for network flows and continued to work on planning systems to improve military emergency scheduling and readiness. Professor Alexander Rinnooy-Kan, a visitor from Erasmus University in the Netherlands, worked on a variety of problems in scheduling and routing, and on a new theory of global optimization for difficult mathematical programs. Professor Magnanti continued to study algorithms for large-scale network design and for network equilibrium. He also worked on modeling and analysis of distribution, facility location, satellite communication, traffic signal, and network reliability systems.

Awards. Research and teaching continue to stimulate each other. In recognition of the area's research accomplishments in information systems and its innovations in curriculum design, the School was one of 13 business schools to receive a major (monetary and equipment) curriculum development grant from IBM. At the area's initiative, the School was also awarded 25 advanced work stations from Xerox to support research in computer-aided decision making. These resources add to those that are available through the Institute's Project Athena. On a personal level, Professor Davis was named one of the top 100 young scientists in America by Science Digest. Professor Graves was appointed a functional area editor for the journal Interfaces. Professors Hauser and Urban received a prize for the best paper presented at the 1984 ESOMAR conference in Rome. Professor Hauser also was acknowledged for the best paper in the Marketing Sciences Literature in 1983. Professor Kaufman was elected a fellow of the American Statistical Association. Professor Little became president of The Institute of Management Science. He also received honorable mention for the best paper in Marketing Science for 1983. Professor Magnanti was appointed one of the first advisory editors to the journal Transportation Science. Professor Marlino was nominated as outstanding graduate woman of the year by the Graduate School of Management at the University of California at Los Angeles. Professor McAllister received an MIT Graduate Student Council award for outstanding teaching. Professor Orlin received a five-year Presidential Young Investigator Award from the National Science Foundation.

EXTERNAL RELATIONS

The School made a further important commitment to alumni/ae relations this year in hiring a new, full-time Alumni/ae Relations Director. Jane M. Morse came on board this spring to oversee alumni/ae activities of the School and help coordinate Sloan School activities with alumni/ae affairs Institute-wide. In June, the Sloan School held the first special reunion dinner dance at the MIT Faculty Club for Sloan graduates of the master's and PhD programs, scheduled to top off a week-long series of alumni/ae events for MIT graduates. The School also sponsored its fourth round of Summer Gatherings, social occasions for alumni/ae and current students of the master's and PhD programs. This year's gatherings took place in Cambridge, New York City, and Los Angeles. They were attended by the Dean, Deputy Dean, and other members of the Sloan School administration and faculty, and attracted over 500 alumni/ae from these areas. The Society of Sloan Fellows organized a regional convocation in Orlando, Florida, in March, to which members of the Sloan School administration and faculty, and attracted over 500 alumni/ae from these areas. The inaugural meeting of a new "Distinguished Sloan Alumni/ae" series featuring Winston Hindle, SM '54, Vice President Corporate Operations at Digital Equipment Corporation. Other regional events were scheduled in a variety of locations such as Washington, DC, and Chicago, often in coordination with local MIT clubs. The Sloan Club Board met twice during the year at Sloan to review the progress of alumni/ae activities and to discuss ways to help the regions develop even stronger alumni/ae organizations at the local level.

Throughout the year, regional clubs of the Sloan Club, the alumni/ae association of the master's and PhD programs, organized additional events for local graduates of all Sloan graduate and undergraduate programs. For example, the Sloan Club of Boston held a series of dinner speaker meetings, including the inaugural meeting of a new "Distinguished Sloan Alumni/ae" series featuring Winston Hindle, SM '54, Vice President Corporate Operations at Digital Equipment Corporation. Other regional events were scheduled in a variety of locations such as Washington, DC, and Chicago, often in coordination with local MIT clubs. The Sloan Club Board met twice during the year at Sloan to review the progress of alumni/ae activities and to discuss ways to help the regions develop even stronger alumni/ae organizations at the local level.

The School's alumni/ae publication, SLOAN, continues to draw rave reviews from its readership. Published twice a year, Winter and Summer, SLOAN features articles on issues of importance in the field of management and at the School.

During the academic year 1984-85 we also continued to strengthen our relationships with the several constituencies that provide financial support to the Sloan School. In consequence, we expect to reach new milestones in all categories of support.

Interaction with our alumni/ae, corporate sponsors, and individual benefactors has increased substantially and the climate of relationships between the School and these friends has never been better. The continuing high reputation of the School among these groups not only helps to increase financial support but also to increase the number and quality of applicants to our regular degree programs and to our executive programs.

Efforts to increase financial support from outside sources for minority graduate students have also resulted in an increase in such support for the next academic year.
As noted in last year's report, the School, in conjunction with the Sloan School Alumni Association (now known as the Sloan Club), established the Miriam Sherburne Fund to honor Miriam for her many years of dedicated service to the Sloan School and its students. Responsibility for this fund-raising was assumed in October 1983 by the Resource Development Committee. To date, a year before the termination of the drive, total collections and pledges stand at close to $140,000. We are very grateful to all those who so generously contributed to this worthwhile purpose.

The School's own efforts in resource development have been greatly facilitated and supported by Professor Samuel A. Goldblith and his MIT Development Office staff, by William J. Hecht and his colleagues at the MIT Alumni Association, and by Glenn P. Strehle, MIT's Treasurer. The Sloan School is most grateful for this continuing spirit of cooperation.

STAFF CHANGES, PROMOTIONS, AND VISITORS

At the start of the 1984-85 academic year, Stewart C. Myers was named the first Gordon Y Billard Professor of Finance. Professor Myers, who has been at the Sloan School since 1966, is a renowned authority on the theory of corporate finance and co-author of the leading textbook in finance, Principles of Corporate Finance. The Billard Chair is named for the donor and one of three chairs established by the 1924 graduate of Course XV.

Four faculty members were promoted to the rank of Full Professor. Gabriel R. Bitran, whose PhD is in Operations Research (MIT, 1975), has been on the faculty since 1978. He specializes in operations management and has made major contributions in developing theoretical foundations for key problem areas of central importance to production and inventory management.

John R. Hauser holds four degrees from MIT and has been on the Sloan School faculty since 1980. A management scientist, whose research and teaching are in the field of marketing, he is widely recognized as one of the field's leading quantitatively oriented scholars.

Paul R. Krugman holds a PhD in Economics from MIT; he has been on the Sloan School faculty since 1980. An outstanding international economist, Professor Krugman most recently has written a number of policy papers on industrial and exchange rate policy and US-Japanese competition. At the conclusion of this year, Professor Krugman decided to continue his association at MIT as a member of the Department of Economics.

Donald R. Lessard specializes in international management, but holds a PhD in Business Administration-Finance from Stanford. A Sloan School faculty member since 1974, Professor Lessard has in the past five years published more than 20 papers on international corporate finance and on issues of economic development and industrial policy.

Three faculty members have been promoted to the rank of Associate Professor. Julio J. Rotemberg was promoted to Associate Professor of Applied Economics. He holds a PhD in Economics from Princeton and has been a member of the Sloan School faculty since 1980. His research focuses on business cycle theory and model estimation and international transmission of economic fluctuations.

Richard S. Ruback, Associate Professor of Finance, holds a PhD from the University of Rochester. His current research interests include capital markets, inflation, industrial organization, and government regulation.

Thomas M. Stoker, Associate Professor of Applied Economics, holds a PhD from Harvard University. Specializing in econometrics, he is currently focusing on statistical and theoretical uses of aggregation in econometrics.

Two new appointments were made to the rank of Associate Professor. Randall Davis was appointed to the rank with tenure. A faculty member with the Department of Electrical Engineering and Computer Science since 1978, Professor Davis joined Sloan's Management Information Systems Group.

Professor Walter W. Powell, who joined the Behavioral and Policy Sciences Area, received a PhD in Sociology from the State University of New York at Stony Brook. Prior to coming to Sloan, Professor Powell held the rank of Associate Professor at Yale University.

One faculty member joined the faculty at the rank of Assistant Professor. Deborah L. Marlino, Assistant Professor of Management Science, works in the field of marketing; she received a PhD in Management with a concentration in Marketing from the University of California at Los Angeles.

Two faculty members transferred to the Sloan School from the Department of Humanities as Lecturers. JoAnne Yates, formerly Assistant Professor of Business Communication, continues to coordinate the Sloan School Writing Program and was joined by Maryanne V. Plotkowski, on a half-time basis.
Stan N. Finkelstein, Associate Professor of Health Management, has accepted a joint appointment as Senior Lecturer in Management and Whitaker College of Health Sciences, Technology and Management.

The Sloan School welcomed a number of visiting faculty this year. Visiting Full Professors included Michael G. S. Denny, from the University of Toronto, who taught Managerial Economics in the fall; Francis McGovern from the Cumberland School of Law who is conducting research and teaching with Professor J. D. Nyhart; Alexander H. G. Rinnooy Kan from Erasmus University in Rotterdam who taught the Combinatorial Optimization subject in the fall semester; Raymond-Alain Thietart, from the University of Paris X-Nanterre, who taught two subjects in Policy and Strategy; and Arthur W. Wright from the University of Connecticut who taught two subjects in Economics.

Visiting Associate Professors included Douglas T. Breeden from Stanford University who taught a subject in Finance Theory; Donald R. Rosenfield, a consultant with A. D. Little, who taught two subjects in Operations Management; Eric J. Johnson from Carnegie-Mellon who taught two Marketing subjects; and Reuven R. Levy, from Saint Louis University, who taught an advanced Information Systems subject.

Visiting Lecturers and Senior Lecturers included in the fall, Sheldon A. Borkin who taught Advanced Computer Systems; John Peingold who taught a Finance Seminar; Brian Bauer and William Frank who taught Management Information Technology; and Joseph P. Vittek, Jr., who taught two sections of Corporate Law for the Modern Manager. In the spring Peter Kubat taught the undergraduate subject in Management Science; Russell W. Olive conducted a workshop for master's students on entrepreneurship; James L. Paddock taught a section of Topics in Financial Management; and E. David Wanger taught Government Regulation in the Workplace.

Three faculty members spent all or part of the year on sabbatical leave. Edgar H. Schein, Sloan Fellows Professor of Management, was away during the spring term; Arnold I. Barnett, Associate Professor of Operations Research and Management, was away for the year; and Stuart E. Madnick, Associate Professor of Management Science, began a one-year leave in the spring term. In addition, five faculty were on professional leaves. They included Ernst R. Berndt, Professor of Applied Economics; John J. Donevan, Associate Professor of Management Sciences; James B. Orlin, Associate Professor of Operations Research and Management; and Richard S. Ruback, Associate Professor of Finance, and Terry A. Marsh, Assistant Professor of Finance, both winners of Batterymarch Fellowships.

Staff changes this year include change in title designations for five key administrators: Alvin J. Silk, Associate Dean of the Sloan School since 1981, became Deputy Dean. Additionally he continues to hold the Erwin H. Schell Professorship of Management to which he was appointed in 1983.

Zenon S. Zannetos, who has had a major responsibility for resource development at Sloan, became Senior Associate Dean for Development while also continuing as Professor of Management. Jeffrey A. Barks became Associate Dean for Undergraduate and Master's Programs; Anne Wood Lipner became Associate Dean for Administration; and Alan F. White became Associate Dean for Executive Programs.

Other staff promotions include Rosemary Brutico, who was promoted from Assistant Managing Editor to Managing Editor of the Sloan Management Review; Sharon Caley, who was promoted from support staff to the job of PhD Program Coordinator; Nancy M. Hack, promoted from support staff to Sponsored Research Staff in the System Dynamics Group; and Grace C. Locke from support staff to Administrative Assistant to the Dean.

New Sloan staff appointments include Elizabeth Goodman, hired to fill the Assistant Managing Editor, Sloan Management Review, slot; Margaret Gutowski, Administrative Assistant to the Deputy Dean; Laura B. Mersky, Administrative Assistant, Management Science Area; and Margaret Daniels Tyler, Coordinator of the Master's Program.

Jane M. Morse, Manager of the joint Sloan-Engineering Management of Technology Program, has also become Director of Sloan's Alumni Relations, half time; and Edwin C. Nevis, formerly Senior Lecturer at Sloan, became Associate Director of Executive Education Programs, a post vacated by the departure of H. Scott Duncan.

Two new Research Staff members were hired to work on the Management in the 1990's Research Project. Kenneth R. Grant, a 1984 MIT graduate in Computer Science, and Constance Perin, formerly a Research Associate in the Artificial Intelligence Laboratory, joined the School as Research Associates.

Finally, as this year draws to a close, we note several departures from Sloan. From the faculty, Associate Professor Harry Katz, Assistant Professors Max Bazerman, H. David Sherman, and Marvin Sirbu, and Senior Lecturer Thomas A. Barocci accepted other positions. Departing Research Staff members include Joel Cutcher-Gershenfeld and Leonard Roseman. From the administrative staff, Kathryn M. Bertrand, H. Scott Duncan, Joanna C. Kosakowski, Gail R. Mann, and Gay Van Ausdall left to accept a variety of other personal and professional challenges. All made worthwhile contributions to the Sloan School and they shall be missed.

ABRAHAM J. SIEGEL
This is my fourth and final report to the President since becoming Dean of Science. As I leave the School of Science to assume the position of Provost, I would like to thank all members of the School -- faculty, students, research, administrative, support and service staff -- for the opportunity to serve as Dean and for the consistent support which I have received during my tenure.

We should never lose sight of the fact that science at MIT is superb, both in its educational and research aspects. Too frequently the inevitable pressure of resource limitations makes us lose sight of the accomplishments of the past and the opportunities of the future. It is our duty to continue to pursue academic excellence and to grasp with enthusiasm and daring the most exciting intellectual possibilities which present themselves from pure mathematics to applied biological sciences. MIT has the history and mission to be the very best and indeed we have an obligation to society to be so. On my departure, I continue to urge all members of the School to press those initiatives which they believe are most important to the future.

I am enormously pleased that Gene Brown has agreed to serve as the next Dean of Science. I have served with Gene Brown on Science Council both as Dean and fellow Department Chairman. During this time I have learned, as have so many others at the Institute, of his enormous wisdom and fairness as well as the great success he has had as Head of the Biology Department. He will make an excellent Dean of Science and I am looking forward to working with him as Provost.

ACADEMIC PROGRAMS

There were 748 undergraduates in the School of Science during the past academic year, a slight increase from the previous year. The number of minority undergraduates remained constant; the number of female undergraduates increased by 2.1 percent. Twenty-one percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science increased from 1,056 in the 1983-1984 academic year to 1,077 in the 1984-1985 academic year. The total enrollment represents 23 percent of the graduate student population at MIT. The number of minority graduate students decreased slightly, and the number of female graduate students increased by 1.5 percent.

There were 279 faculty members in the School this past year. This represents a slight decrease from the previous year. The undergraduate student-to-faculty ratio was 2.7 to 1, and the graduate student-to-faculty ratio was 3.8 to 1.

RESEARCH

The FY'85 volume of the School of Science was approximately $85,250,000. This represents a five percent increase from the previous year.

SPECIAL EVENTS

On October 3, Dr. Frank Press, President of the National Academy of Sciences and former Head of the Department of Earth and Planetary Sciences, gave the inaugural lecture of a series marking the 20th anniversary of the dedication of the Cecil and Ida Green Building -- home of the Department of Earth, Atmospheric, and Planetary Sciences. The building was made possible by the generosity of Mr. and Mrs. Cecil H. Green, who were the guests of honor at a dinner to mark this anniversary.

FACULTY

I am pleased to report the following honors and awards received by faculty this past year. Professor Leigh Royden, Kerr-McGee Career Development Professor and Assistant Professor of geology and geophysics in the Department of Earth, Atmospheric, and Planetary Sciences, was awarded a NATO Postdoctoral Fellowship by the National Science Foundation and the Department of State. In the Department of
Mathematics, Professor Gilbert Strang was elected to the American Academy of Arts and Sciences, and Professor David Jerison was the recipient of a Sloan Foundation Fellowship. Professor Robert A. Weinberg, Department of Biology and Whitehead Institute, was one of six members of the MIT faculty elected to the National Academy of Sciences. The Fresenius Award of Phi Lambda Upsilon, the chemistry honor society, was awarded to Professor Mark S. Wrighton of the Department of Chemistry. Institute Professor Nevin S. Scrimshaw was elected Fellow of the American Institute of Nutrition.

Promotions to Full Professor effective July 1, 1985 include Professors Robert Langer and R. Alan North, of the Department of Applied Biological Sciences. Tenure was awarded to Professors Timothy Grove of the Department of Earth, Atmospheric, and Planetary Sciences and Alexander Klibanov of the Department of Applied Biological Sciences.

Several faculty have been appointed to professorships effective July 1, 1985. Among them is Professor Robert Ledoux of the Department of Physics, who is one of the first two holders of the Cecil and Ida Green Career Development Professorship. Appointments to this Chair are made to recognize and encourage excellence in teaching.

We were saddened by the death of Professor William Buechner, former Chairman of the Department of Physics and an internationally known Experimental Nuclear Physicist.

JOHN M. DEUTCH
Department of Applied Biological Sciences

The year was one of significant change for the department. Effective February 1, 1985, the name of the department was officially changed from Nutrition and Food Science to Applied Biological Sciences. This change was authorized in response to a request by the faculty, who were unanimous in the opinion that the name Nutrition and Food Science was inappropriate because it was no longer descriptive of the educational and research activities that make up most of its current programs. In contrast, the new name is sufficiently broad not only to encompass current programs, but also to provide flexibility for further growth and evolution consonant with future developments in the underlying sciences.

The change resulted from a redefinition of departmental objectives in which the faculty sought to define areas of scientific endeavor which, by virtue of their intellectual challenge, technological character and societal value could take advantage of current strengths as well as efforts of new faculty to be appointed. Areas were also identified whose attributes would enhance intellectual interactions among members of the faculty and students within the Department as well as offering opportunities for similar interactions with members of other departments and laboratories.

Several areas possessing these attributes have been identified, including those of biotechnology, toxicology and molecular pharmacology. We anticipate that these will represent major areas of concentration of the research and educational activities of the Department, and new faculty appointments will be made with a view to strengthening them, in particular the area of biotechnology. In recruiting new faculty members, we are seeking to identify individuals whose qualifications represent the combined qualities of excellence in scholarship, serious interest in applied aspects of their work, and commitment to education.

FACULTY

Two new faculty appointments were made during the 1984-85 academic year. Dr. Renee Fitts was appointed Assistant Professor in October, 1984, having previously held the position of Manager of Diagnostic Research at Integrated Genetics, Framingham, Mass. Dr. Fitts received her B.A. in Biology from the University of Chicago and her Ph.D. in Microbiology from the University of Colorado in 1980. During her postdoctoral training and her employment at Integrated Genetics, she opened an exciting new field of research, identifying DNA sequences in Salmonella which are unique and specific to all members of that genus but not to other bacteria. These findings have significance in that identification of new DNA sequences acquired by this organism may help to define sources of their virulence. They also provide the basis for a rapid diagnostic test for these organisms.

Dr. Marie Chow joined the faculty in January 1985, also as Assistant Professor. She received her undergraduate degree in chemistry from Smith College in 1974, and continued her education at Yale University where she received her Ph.D. degree in molecular biophysics and biochemistry in 1981. Her thesis research concerned the DNA replication of the parvovirus, Minute Virus of Mice (MVM). During her postdoctoral training with Dr. David Baltimore at MIT, she continued her research on mammalian viruses in studies of the molecular biology of poliovirus. The thrust of her research program has been the development of an experimental approach with which neutralization of poliovirus can be studied at the molecular level.

Several changes also occurred among members of the tenured faculty. Dr. Paul Newberne, Professor of Nutritional Pathology and Dr. George Wolf, Professor of Physiological Chemistry assumed Senior Lecturer (Professor Emeritus) status, effective June 30, 1984. Dr. Lance Taylor, Professor of Nutritional Economics accepted a joint appointment as Professor in the Departments of Economics and Urban Studies, effective February 1, 1985.

Dr. Michael Holick, Associate Professor of Nutritional Biochemistry resigned, to accept a position at the Tufts University Human Nutrition Center, effective July 1, 1985. Dr. Michael Baum, Associate Professor of Behavioral Endocrinology also resigned to accept a position as Associate Professor of Psychology at Boston University.

EDUCATIONAL ACTIVITIES

During this academic year, undergraduate majors enrolled in the program Applied Biology (Course VIIIB) numbered 42 during the Fall '84 term and 36 during the Spring '85 term. In addition, there was strong participation of faculty and staff in UROP projects for undergraduates. In all, a total of 21 faculty members supervised research projects for an average of 34 students during each of the academic terms (summer, fall, and spring). Other interactions with undergraduates included participation as freshman advisors (9) and pre-medical advisors (6).
With respect to undergraduate education, the Department continues to offer an undergraduate curriculum in Applied Biology as part of the Life Sciences program (Course VIIIB). In its current form, it represents a pre-professional program preparing students for graduate study in the general areas represented by the existing graduate degree programs. We are currently engaged in a detailed examination of the departmental role in undergraduate education within the Institute and in particular, an analysis of unique potential contributions that could be made by members of the faculty. The objective of this analysis is to redefine our role in undergraduate education in view of the reorientation of research and graduate education programs, with the ultimate goal of increasing the level of involvement through either the existing framework or through development of a separate departmental curriculum.

Reassessment of research activities has been accompanied by significant changes in the graduate degree programs of the Department. For the past decade, the Department has offered programs leading to doctoral degrees in five areas. Although they shared a few common features, these programs operated with a substantial degree of autonomy, permitting only limited opportunities for interactions among students and faculty. Recognizing the detrimental educational impacts of this organizational structure, the faculty is developing plans for a new curricular structure which provides for a much greater degree of commonality in core subjects, while preserving adequate opportunities for specialization in advanced subjects. This curriculum will be instituted during the 1985-86 academic year, with the intent of offering a single departmental degree (in Applied Biological Sciences), for future graduates.

The number of graduate students enrolled as SM or PhD degree candidates numbered 119 during the Fall term and 115 during the spring term of the 1984-85 academic year. Doctoral degrees were awarded to 14 students, and SM degrees to 5.

GERALD N. WOGAN
In the past year, 270 undergraduates were registered as Life Sciences majors, and 95 received the degree of Bachelor of Science in Life Sciences. Of these, 71 were in the regular Course VII program, 11 in the VII-A Program, and 13 in the VII-B program. Most of these graduates will attend either medical school or graduate school.

During the period from July 1, 1984, to June 30, 1985, 21 Ph.D. degrees were awarded in the Department and two in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute. The maximum number of Ph.D. candidates registered in the Department in 1984-1985 was 147, with another 18 in the Joint Program. The entering class in 1984 was 28 and the class arriving in September, 1985, will be 30.

Educational Activities

In the past year several changes were implemented in the undergraduate curriculum, the most important of which was the introduction of a new subject in Molecular Biology (7.08) required of all Life Science majors. This new subject was taught by Professors Harvey Lodish and Barbara Meyer and was well received by the students. In the coming year, we will offer another new subject, 7.09 Cellular Neurobiology. We have felt for some time that our undergraduate curriculum should include an offering in cellular aspects of neurobiology, but had no one in the Department with the training and interest to teach such a subject. With the three recent appointments of Drs. McKay and Quinn (joint with Biology and the Whitaker College) and Burden (in Biology) we now have the resources to expand our undergraduate curriculum with this offering.

The recipient of the John L. Asinari award for 1984-1985 for outstanding research by undergraduates in Life Sciences was Raymond Kelleher III (supervisor, Professor Alexander Rich).

We have recently reviewed the graduate curriculum in the Department and made recommendations for modification of our offerings in the areas of cell biology and immunology. With the rapid development of the field of cell biology in the past few years, our one lecture subject, 7.60 Cell Biology, no longer covers the field of cell biology in sufficient depth. We requested permission to reorganize 7.60 and to offer an additional term of Cell Biology, to provide a more complete education for graduate students wishing to become professionals in cell biology. These courses will be 7.60 Cell Biology I and 7.61 Cell Biology II. In the area of immunology, we recommended significant modification of 7.63 Immunogenetics and Cellular Immunology (including name change to 7.63 Immunology for Graduate Students) in order to keep our graduate students better informed in this rapidly developing area. We also recommended that 7.73 General Immunology be changed from a graduate to an undergraduate subject. All of these changes have been approved by the Subcommittee on Graduate Subjects and the Committee of Curricula for implementation in 1985-1986.

Research

The research activities of the Department are in the areas of biochemistry, genetics, microbiology, cell and developmental biology, virology, and immunology. Individual research projects are described in the annual publication, Biology Research Summaries, available in the Biology Headquarters Office (56-511).

Personnel

During the past year, Drs. Leonard P. Guarente and Monty Krieger were promoted to Associate Professor, and Dr. David E. Housman to Full Professor, effective July 1, 1985.

Dr. Salvador Luria, Institute Professor, Emeritus, retired as Director of the Center for Cancer Research, and Dr. Phillip A. Sharp was promoted from Associate Director to Director, Center for Cancer Research.

Dr. Graham C. Walker spent his sabbatical leave in the laboratory of Dr. Sharon Long at Stanford University working on Rhizobium nodulation.

Dr. Hara Ghosh, Chairman of the Department of Biochemistry at McMaster University, spent his sabbatical year in the laboratory of Professor Phillip A. Sharp, and Dr. John Moner of the University of Massachusetts spent his sabbatical leave in Professor Sheldon Penman's laboratory.

Dr. Brent H. Cochran joined the Department and the Center for Cancer Research as Assistant Professor on June 1, 1985. Dr. Cochran received the S.B. in Biology from M.I.T. in 1978 and the Ph.D. in Microbiology and Molecular Genetics from Harvard University in 1984. He was a Postdoctoral Fellow at the Dana Farber...
Dr. Cochran's research interests are in the area of molecular mechanisms of cell growth regulation.

Dr. Hee-Sup Shin 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 on July 1. Dr. Shin received the Bachelor's degree in 1970 and the M.D. degree in 1974 from Seoul National University, and the Ph.D. degree in Genetics and Cell Biology from the Sloan-Kettering Division of the Cornell University Graduate School of Medical Sciences in 1983. From 1983 to June 1985 he has been a Research Associate at the Sloan-Kettering Institute. Dr. Shin's research interests are in the area of the molecular and genetic analysis of mammalian differentiation.

It is a pleasure to report the following honors and awards received by various faculty members in the past year. Professors David Botstein, Mary Lou Pardue, and Christopher Walsh were elected to the American Academy of Arts and Sciences; Professor Pardue has also been appointed to a four-year term on the National Advisory General Medical Sciences Council, and was elected president of the American Society of Cell Biologists. Drs. Brent Cochran and Earl Ruley both received awards as Rita Allen Foundation Scholars; Professors Jonathan King and Paul Schimmel were elected Fellows of the American Association for the Advancement of Science; Dr. Monty Krieger was awarded the 1985 Science Council Prize for excellence in undergraduate teaching, and also the Graduate Student Council department teaching award; Dr. Ronald McKay was appointed Edward J. Poitras Associate Professor in Human Biology and Experimental Medicine; Dr. Barbara Meyer will be appointed Whitehead Institute Career Development Assistant Professor of Biology effective July 1; Dr. Richard Mulligan received a Research Career Development Award from N.I.H.; Dr. William Quinn won a McKnight Neuroscience Development Award, one of 14 given this year to support investigative programs of neuroscientists with outstanding promise; Professor Phillip Sharp received the Howard Taylor Ricketts Award from the University of Chicago for his research on splicing of RNA; Professor Susumu Tonegawa has been declared a living national monument of Japan and awarded the Order of Culture by the Emperor of Japan; and Professor Robert Weinberg was awarded an American Cancer Society Research Professorship.

It is with regret and sadness that I report the deaths of Professor David Waugh in October, and of Mr. Randall Chipperfield, a graduate student, in February. Professor Waugh received the A.B. degree in zoology in 1935 and the Ph.D. degree in physiology in 1940, both from Washington University in St. Louis. He joined the faculty at M.I.T. in 1941, and was recognized as an authority on the chemical and physical processes involved in the coagulation of blood, on milk proteins, and on the chemical and physical processes involved in the interaction of protein molecules. Professor Waugh had planned to retire at the end of this academic year. Mr. Chipperfield, a 1980 graduate of the University of Calgary, had completed all of the requirements for the Ph.D. in biology (supervisor, Professor Robert Weinberg) at the time of his tragic death.
Bachelor of Science degrees in Chemistry were awarded this year to 25 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 1 person. A total of 40 Ph.D. degrees were awarded: 9 in September; 12 in February; 19 in June. To date 1783 Ph.D. degrees and 403 Masters degrees have been awarded by the Department.

PERSONNEL

Professor Richard R. Schrock was awarded the first annual Award in Organometallic Chemistry, sponsored by the American Chemical Society.

Professor Stephen Lippard was awarded the 1985 Henry J. Albert Award of the International Precious Metals Institute in recognition of his research contributions in Platinum Chemistry and its Application to Nucleic Acids.

Dr. Dagmar Ringe, Lecturer and Director of the Undergraduate Chemistry Laboratory was the first recipient of the Margaret Oakley Dayhoff Award presented by the Biophysical Society for her research work on x-ray crystallography.

Professor Keith Nelson was selected by the national Science Foundation to receive a five year Presidential Young Investigator Award.

Professor K. Barry Sharpless was elected to the National Academy of Sciences, and Professor Christopher Walsh was elected to the American Academy of Arts and Sciences.

Dr. John M. Deutch, Arthur C. Cope Professor of Chemistry, and Dean of the School of Science, becomes Provost of MIT on July 1, 1985.

ACTIVITIES OF THE DEPARTMENT

The Department was privileged to host several lecture series during the past year. They were as follows: Professor Helmut Beinert, Institute for Enzyme Research, University of Wisconsin-Madison, T.Y. Shen Visiting Professor in Medicinal Chemistry; Professor E.J. Corey, Harvard University, Karl Pfister Visiting Professor; Professor Eric J. Heller, University of Washington, Arthur D. Little Visiting Professor; Professor Albert Eschenmoser, ETH-Zurich, Karl Pfister Visiting Professor; Professor Sidney M. Hecht, University of Virginia, T.Y. Shen Visiting Professor in Medicinal Chemistry; and Professor W.A. Herrmann, Johann Wolfgang Goethe-Universitat, Arthur D. Little Visiting Professor.
FACULTY AND RESEARCH STAFF

Professor Keiiti Aki left the Department on July 1, 1984, to become W.M. Keck Professor of Geological Sciences at the University of Southern California, and Professor Thomas Jordan succeeded him as Robert R. Shrock Professor when he was appointed Full Professor on July 1, 1984. Professor B. Clark Burchfiel took over the Schlumberger Chair relinquished on July 1, 1984, by Professor Irwin Shapiro. Two new Assistant Professor appointments on July 1, 1984, were Dr. Leigh Royden and Dr. Gregory Duckworth. With her appointment, Dr. Royden also became the first holder of the Kerr-McGee Career Development Chair. Professor Gordon Pettengill took leave on July 1, 1984, to become Director of the Center for Space Research at MIT. Other promotions effective July 1, 1984, included that of Professor D. Edmunds Harrison to Visiting Associate Professor and Drs. Vernon Cormier and Bruce Fegley to Principal Research Scientist. Two faculty — Professors Frederick Sanders and William Pinson — retired on July 1, 1984.

Dr. William Young was appointed Assistant Professor, beginning February 1, 1985. Dr. Jack Wisdom joined the Department on July 1, 1984, as Research Scientist, and on July 1, 1985, will become Assistant Professor. Another Assistant Professor appointment on that date, in the field of radar meteorology, will be Dr. Earle Williams. Professor James Elliot will be promoted to Full Professor and Professors Paola Rizzoli and Kerry Emanuel to Associate Professor on July 1, 1985. Also on July 1, 1985, Drs. Robert King and Christopher Measures will be promoted to Principal Research Scientist. Two of our faculty resigning on June 30, 1985, were Professors Frank Spear and Richard Passarelli.

Honors

Professor B. Clark Burchfiel was elected a member of the National Academy of Sciences in April, 1985; he also was a 1985 recipient of a Guggenheim Fellowship. In recognition of his research in transition metal geochemistry and mineral spectroscopy, on December 1, 1984, Professor Roger Burns was conferred a Doctor of Science degree from Oxford University, England, where he was a faculty member 15 years ago.

In 1984, Professor Charles Counselman was elected a Fellow of the American Geophysical Union. Professor Richard Lindzen received the Charney Award of the American Meteorological Society. Professor Leigh Royden was presented with a 1985 Presidential Young Investigator Award by the National Science Foundation.

ENROLLMENT

Our graduate enrollment for the academic year just ended was 173, with 63 being Joint Program students at Woods Hole Oceanographic Institution. The undergraduate enrollment was 38. The annual geology field camp took place as usual in Nevada in January, 1985.

RESEARCH

Geology/Geochemistry

Professor B. Clark Burchfiel has field research projects in the western United States, Sweden, Bolivia, Greece and China. Studies in California have indicated that Panamint Valley was formed during the past three million years. The valley developed by crustal extension on a west-dipping low-angle normal fault at an average rate of 3 mm/year. The valley contains only a few hundred meters of sedimentary fill that was probably deposited directly on the developing low-angle fault surface. Similar processes may have led to a progressive development of the Basin and Range Province during the last 40 million years.

Spectroscopic techniques continue to be developed and applied by Professor Roger Burns to new problems involving transition metal cations in minerals. For example, using Mossbauer spectroscopy and focussing first on annite, an iron-rich mica first discovered last century at Cape Ann, Massachusetts, Burns demonstrated that substantial amounts of ferric iron occur in biotites. These iron-rich biotites co-exist with cation-deficient magnetites and fayalites, indicating that many New England granites crystallized under relatively oxidizing conditions.

Professor Fred Frey has continued earlier studies on alpine peridotites, especially the Ronda high-temperature peridotite in southern Spain, and found systematic compositional trends that result from segregation of partial melts. Unlike mantle inclusions in basalt, there is little evidence for mantle metasomatism.
Through studies of compositionally zoned basaltic lava flows in the Cascades, Professor Tim Grove has obtained a quantitative measure of the interaction of mantle-derived basalt with the overlying crust in the Cascade continental arc. Our studies show that a key role in the generation of some Cascade andesites is a large amount of assimilation of crust by basaltic magma. Crystallization of large volumes of basaltic magma occurs, releasing latent heat which heats and melts the surrounding crust.

Professor Stan Hart has delineated a large-scale isotopic anomaly in the southern hemisphere mantle, using available Sr and Pb isotopic data for basalts from oceanic islands. The anomaly is globe-encircling in extent, centered on 30°S latitude. The isotopic signature of this DUPAL anomaly requires a mantle source in which enrichments of Rb/Sr, U/Pb and Th/U have existed for periods of time in excess of 3 b.y. The presence of this old-large-scale, coherent mantle anomaly places severe constraints on models for mantle convection.

Professor Kip Hodges has been studying continental extension in the Basin and Range province of the US and has found that deformation concentrated on discrete, low-angle shear zones has been responsible for up to 20 km of Cenozoic crustal thinning in the Basin and Range.

Dr. Nobu Shimizu has been experimentally determining self-diffusion coefficients of Mg, Ca, Si and O in silicate liquids as a function of pressure, temperature and chemical composition, using a diffusion couple method involving enriched isotopes and an ion microprobe as analytical tool. The results on the binary melt system diopside-jadeite show that (1) the diffusion unit for Si changes from Si ion in depolymerized diopside melt to SiO4 ion in polymerized jadeite melt; (2) Mg, Ca and O diffuse as individual ions regardless of polymerization; (3) the effects of polymerization on diffusivity of Mg and Ca, network modifiers, suggest that coordination numbers for these elements are different (indicating that Mg may have fourfold coordination).

Professor John Southard has used experimental studies of particle orientation and particle density distribution to develop better ways to interpret the environment of deposition of ancient sedimentary rocks.

Studies of eclogites from Austria by Professor Frank Spear have shown that eclogites do not crystallize along subduction geotherms, but show rapid increases in pressure at nearly constant temperature, suggesting that continental subduction is episodic and not a continuous process.

Geophysics

Dr. Arthur Cheng has developed a technique to measure in situ permeability, using the Stoneley wave in the borehole, which is applicable to both porous rocks and fractures. The Stoneley wave attenuation can be related to the formation or fracture permeability. This method is currently being field tested and compared with other in situ permeability measurements such as the pump test and the packer test.

Dr. Vernon Cormier has extended a technique for synthesizing the strong ground motion of an earthquake to include the effects of 3-D crustal structure, as well as the effects of an extended, complex rupture history. The technique has been applied to the analysis of accelerograms from the 1984 Morgan Hill, California, earthquake. Strong trade-offs of rupture history with 3-D structure have been found in a 4 km zone of fault gouge centered on the surface trace of the fault.

Professor Gregory Duckworth has developed signal processing algorithms that allow high resolution measurement of the ocean and crustal velocity structure beneath the Arctic ice cap. The multi-channel array processing algorithms and inversion procedures also allow separation of the effects of under-ice rough surface scattering and effective attenuation in the sea-bed, providing some of the most detailed measurements to date in this remote area.

Professor Brian Evans is studying diffusion-induced grain migration in minerals systems. It is now clear that DIGM can occur in the calcium carbonate-strontium carbonate system at temperatures of 650-800°C; this is the first documented observance of this phenomenon in minerals under laboratory conditions. Further experiments are underway to investigate the likelihood of natural occurrence.

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 has combined a detailed gravity analysis with a tomographic map of upper mantle seismic velocity anomalies in the Transverse Ranges of California to show that up to 250 km of continental lithosphere from southern California has been subducted beneath central California over the past 4 million years. Her results imply that California is shrinking at the rate of 60 mm/yr.
Professor Peter Molnar is continuing his field investigation of active faulting in China in collaboration with geologists from the People's Republic of China. He estimates an east-southeastward displacement of southeast China with respect to Siberia at an average rate of about 2 cm/yr.

A global study of intermediate wavelength depth and geoid anomalies using GEOS-3 altimeter measurements has been completed by Professor Barry Parsons. Good correlations between depth and geoid anomalies are observed at these wavelengths, in particular over features like the Bermuda Rise. Theoretical work on the geoid and depth anomalies calculated for convective flows that have been determined using numerical methods suggests that such anomalies primarily reflect temperature variations within the upper thermal boundary layer of convection occurring beneath the lithosphere.

Professor Thomas Jordan has established that lithospheric plates being subducted beneath the island arcs of the western Pacific penetrate to depths exceeding 1000 km, several hundred kilometers greater than indicated by seismic activity. These observations place significant constraints on models of mantle dynamics; in particular, they disagree with recent proposals that the convective system which drives plate tectonics is confined above 700 km depth.

Dr. Steven Roecker has determined the three-dimensional seismic wave velocity structure in the New Hebrides subduction zone. Two noteworthy results of this investigation are the correlation of high velocities with regions of low seismicity and the discovery of 70 km depth earthquakes within the oceanic lithosphere directly beneath the trench.

Professor Leigh Royden has been using several techniques to evaluate the thermal structure and evolution of the lithosphere in recently active tectonic environment. These include analysis of subsidence, heat flow and organic maturation in sedimentary basins, and metamorphic temperatures and pressures in eroded mountain belts. Such studies should yield insight about the organization and formation of these tectonic systems at depth.

Professor Gene Simmons has shown that granites contained healed microcracks, that rare earth elements are mobile and have migrated in the geologic past, and that microcracks have provided the pathways for the migration of uranium.

Professor Sean Solomon has found that the depth to which earthquake faulting extends along midocean ridges is variable, but generally greatest at the slowest spreading rates - a pattern consistent with a spreading model in which magma injection is episodic and circulation of seawater along cracks and faulted flowpaths can locally cool the entire crust to temperatures at which rocks deform in a brittle manner. The mechanisms and distribution of earthquakes in young oceanic lithosphere appear to be the result of thermal stress generated during cooling of the spreading oceanic plate.

Professor Nafi Toksöz has been working intensively to understand the physical basis of earthquake prediction and to resolve why it is possible to predict some earthquakes, but not others which have been monitored just as intensively. Based on his research on earthquakes from the United States, China, Japan, and other parts of the world, he relates the predictability to fault zone asperities.

Dr. Joseph Walsh has been analyzing changes in gravity resulting from earthquake faulting. Using a new technique, he is extending his previous theoretical analysis of faulting in a half-space to the problem of an elastic layer over a half-space having different properties.

**Meteorology**

Professor Randall Dole has continued studies on the phenomenology of anomalous flow patterns that persist beyond the periods associated with synoptic scale variability. His work indicates that persistent anomalies typically occur in one of three primary regions: the North Pacific to the south of the Aleutians, the North Atlantic to the southeast of Greenland, and from the northern Soviet Union north-eastward to over the Arctic Ocean.

Professor Kerry Emanuel is working on a nonlinear analytical model of the formation of tropical cyclones which attributes the growth of the cyclone to a nonlinear instability based on air-sea interaction. He is also investigating the dynamics of two-dimensional precipitating convection using a simple linear model.

Dr. Bruce Fegley has modelled the chemistry of the deep atmospheres of Saturn and Uranus. His calculations predict that N₂, PH₂, and GeH₄ are important tracers of atmospheric dynamics on these planets.

Professor Richard Lindzen is currently studying the underlying mechanisms of shear instability in fluids, stationary planetary waves and regional climate, and 100 K year cycles in glaciation.

Professor Edward Lorenz has developed a simplified atmospheric circulation model which includes the thermodynamic and radiative effects of atmospheric water. A numerical solution advancing in six-hour time steps for 500 years exhibits irregular free variations of the global mean temperature with amplitudes of one to two degrees and periods ranging from 1 to 100 years.
Professor Reginald Newell has used monthly mean data from the past twenty-five years to show that inter-annual atmospheric carbon dioxide concentrations are positively correlated with tropical sea surface temperatures, with the ocean leading by several months. The findings have been applied to explain the low values of carbon dioxide which occurred during the last ice age.

Professor Ronald Prinn is leading a follow-on to the Atmospheric Lifetime Experiment (ALE) called the Global Atmospheric Gases Experiment (GAGE). This experiment, which began in November, 1984, will provide continuous measurements over the globe of a suite of trace gases (N₂O, CH₄, CFC₁₂, C₂HCl₂, CH₃CCl₃, CCl₄, C₂F₃Cl) important in the "greenhouse effect" and in global atmospheric chemistry. He is also co-chairing the development of the Global Tropospheric Chemistry Research Program, which is a major new national and international initiative in atmospheric chemistry.

Professor Peter Stone has extended his work on how large scale eddies force the general circulation of the atmosphere by developing a diagnostic function describing the total eddy forcing of the atmosphere's moisture field. Calculations of this function show that the eddies tend to increase the moisture in mid-latitudes three times more strongly than was previously thought to be the case.

Dr. Earle Williams has demonstrated the importance of space charge distribution in influencing the geometry of electrical discharge paths in laboratory scale charged clouds. These findings have suggested new radar measurements of lightning in thunderclouds which are currently in progress.

Oceanography

Professor Ed Boyle has introduced time-dependent anthropogenic lead deposition into a model of the oceanic thermocline constructed by Helium 3 and tritium data. Comparison of the model with field data (generated in his lab and by other investigators) indicates that lead in the upper water of the North Atlantic is largely advective; i.e. little chemical reactivity need be invoked to account for ocean displacement of lead.

Professor John Edmond has begun a major geochemical program in the Orinoco Basin of Venezuela, with logistical support from the Government of that country. A combination of boats, aircraft and helicopters gives access to some of the remotest areas of the Americas. While the primary mission is to establish a scientific data base to guide resource exploitation, the opportunity has been presented to make a comprehensive study of the geochemistry of this major river basin.

Professor Charles Eriksen has found vertically propagating equatorial waves of several kilometer wave-length at annual and higher frequencies from two years of deep moored measurements in the central Pacific. These waves represent an energy sink to wind-forced near-surface motions, including El Niño.

Professor Glenn Flierl has derived theoretically the pattern of circulations and the rate of spin-down inducing by mixing processes in an oceanic vortex. He has explored the mechanisms which produce mixing, and is currently testing these ideas against the data from the Warm Core Rings experiment.

Dr. Chris Measures' shipboard trace element program has been extended, adding two oxidation states of chromium to the existing suite of beryllium, aluminium and selenium. The techniques have now been used three times in the Atlantic and Western Pacific oceans. The advantage of real time analyses has been highlighted by the ability to detect and examine trace elements in limited scale features such as elevated levels of aluminium in the 18° mode water in the Northwestern Atlantic.

Professor Paola Rizzoli has focused her research upon the study of the Gulf Stream System. She has carried out a Gulf Stream experiment using acoustic tomography, with bottom mounted instruments, in October, 1984, with the goal of mapping the Stream density structure. Theoretically she has modeled the Gulf Stream as an unstable jet capable of radiating highly nonlinear wave radiation and coherent eddies into the far field.

Professor Carl Wunsch is continuing his role in organizing a global experiment for observing and understanding the general circulation of the ocean. This experiment, called the World Ocean Circulation Experiment (WOCE), will bring together an international effort over a decadal time span directed toward deploying satellites and in situ observations. The program will employ ships, satellite scatterometers and altimeters, gravity measurements, acoustic tomography, chemical tracers, drifting floats, and many other observational tools.

Planetary

Professor Charles Counselman's group has connected earth-satellite tracking receivers to a network of radio telescopes spanning thousands of kilometers, in order to monitor strains in active regions of the earth's crust. The large network serves to determine the orbits of the satellites with respect to an inertial frame defined by extragalactic radio sources. Radio signals emitted by the satellites are used by small field instruments to measure regional strain. A strain of one-millionth can be resolved in just a quarter of an hour.
Professor Jim Elliot and Dr. Richard French have analyzed Uranian ring occultation data obtained at different wavelengths in order to determine the sizes of the ring particles. They have found that less than 10% of the particles are submicron-sized.

Professor David Jewitt has followed the development of comet Halley, using charge coupled device detectors. The first substantial mass loss from the nucleus occurred at a heliocentric distance of 5 AU. So far, the mass loss appears to have been controlled by the sublimation of water ice from the nucleus.

Professor Gordon Pettengill has obtained radio emission measurements of Venus and Mercury, using the Very Large Array (VLA) to achieve a substantial resolution of their surfaces. In addition to noting regions of anomalously low emissivity on Venus (in confirmation of earlier spacecraft observations), he has obtained measurements of the polarization of the emitted thermal radiation from both planets.

Professor Jack Wisdom has shown that the chaotic zone which accompanies the 3/1 mean motion commensurability with Jupiter provides a dynamical route for the transport of meteoritic material from the asteroid belt directly to Earth.

Dr. Robert King is using laser ranging observations of the moon to study variations in the earth's rotation. Essentially all of the observed variation on time scales of a few days to a year can be explained by tidally-induced changes in the earth's moment of inertia, and exchange of angular momentum between the atmosphere and solid earth.

WILLIAM F. BRACE
Department of Mathematics

ACADEMIC PROGRAM

During the 1984-85 year there were 197 undergraduates and 132 graduates majoring in mathematics. The Bachelor of Science was awarded to 59 students, including 15 second majors. There were five recipients of the Master of Science and 27 recipients of the Doctor of Philosophy in Mathematics.

A new degree, "Bachelor of Science in Mathematics with Computer Science", has been approved by the MIT faculty and will be awarded starting in 1985-86. This degree program was designed by Professors Leighton and Sipser and is intended to provide a more visible framework for the study of theoretical computer science within the Mathematics Department. The requirements for the new degree are rather stringent. They include enough subjects to qualify for a general mathematics degree, together with four Course VI computer science subjects. Of the current freshman class, so far 13 have selected this new degree program.

Two proposals to Project Athena for the development of software for certain freshman and sophomore subjects in our present curriculum have been funded: Interactive Differential Equations Graphics (Professors Mattuck and Morgan) and Computer-based Exercises for Introductory Linear Algebra and Applied Mathematics (Professors Strang, Kleitman, Rosales). Field-testing of developed materials will occur during the academic year 1985-86.

FACULTY CHANGES

We were saddened by the death of Professor Emeritus Prescott Crout. Professor Crout died suddenly while vacationing with his wife in Switzerland.

Three faculty members retired this year: Professor Warren Ambrose, after 38 years of service; Professor Herman Chernoff, after 12 years of service to accept an appointment at Harvard; and Professor George Whitehead, after 36 years of service. They were honored at a luncheon at the Faculty Club and by a dinner at President Gray's home.

Professor Willem Malkus will succeed Professor David Benney as Chairman of the Applied Mathematics Committee. Other faculty who will continue their present appointments are: Professor Franklin Peterson, Chairman of the Pure Mathematics Committee; Professor Nesmith Ankeny, Chairman of the Graduate Committee and Professor David Vogan, Chairman of the Undergraduate Mathematics Committee.

Associate Professor Michael Sipser was awarded tenure.

F. Thomson Leighton and Rodolfo Rosales were promoted to the rank of Associate Professor.

Professor Daniel Quillen has taken a leave of absence to accept a chair at Oxford for three years.

Professor Steven Orszag resigned to accept a joint appointment in the Mechanical Engineering and Mathematics Departments at Princeton.

Assistant Professors who have resigned are: S. James Gates, to join the Department of Physics at the University of Maryland; Jeff Kahn, Rutgers University; Andrew Fowler, University of Oxford; Gary Miller, Computer Science Department, University of Southern California; Ravindran Kannan, Computer Science Department, Carnegie Mellon University.

The Department has appointed four new Assistant Professors of Applied Mathematics for the fall of 1985. They are David Schmoys and Baruch Awerbuch (Computer Science); C. Frederick Pearson (Fluid Dynamics); Nicholas Warner (Theoretical Physics). Antonio Sanchez-Calle was appointed Assistant Professor of Pure Mathematics.

Faculty on leave during the year were: Daniel Kleitman (year); Gil Strang (spring); Alar Toomre (spring) Harold Stark (spring, University of Southern California); Michele Vergne (fall, CNRS, France); S. James Gates (fall, University of Maryland); William Goldman (Mathematical Sciences Research Institute, Berkeley); Jeff Kahn (Rutgers University).
Visiting the Department this year were: Jochen Bruning (West Germany); Paul Malliavin (France); Ivan Todorov (Bulgaria); Curtis Green (Haverford); Dorian Goldfeld (Harvard); Kenneth Berman (Wesleyan).

FACULTY HONORS AND AWARDS

Professor Herman Chernoff received an honorary doctoral degree from Technion, the Israel Institute of Technology.

Professor Daniel Freedman received a Guggenheim Fellowship. Professor Freedman will be on leave in the fall in Paris.

Professor Harvey Greenspan received a Fairchild Fellowship.

Professor Victor Guillemin was elected to the National Academy of Sciences.

Associate Professor David Jerison received a Presidential Young Investigator Award from the National Science Foundation.

Professor George Lusztig received the American Mathematical Society Cole Prize in Algebra for his work in representations of finite groups. The prize is given every five years; Daniel Quillen was our previous winner.

Associate Professor Frank Morgan is one of the first two holders of the Cecil and Ida Green Career Development Professorship, a new two year chair which recognizes excellence in teaching.

Professor Gian-Carlo Rota was awarded an honorary doctoral degree from the University of Strasbourg. This award is the highest honor given by a French university.

A National Medal of Science was awarded to Professor Isadore Singer for his work in differential geometry, on the index theorem for differential operators, and for his applications of geometry and topology to theoretical physics. Professor Singer received the award in a ceremony with President Reagan at the White House.

Professor Richard Stanley received a Fairchild Fellowship.

Professor Alar Toomre was awarded a MacArthur Prize Fellowship for his work in astrophysics. This is an award given by the John D. and Catherine MacArthur Foundation to recognize and give talented individuals the financial freedom to pursue their interests.

Professor Ka-Kit Tung received a Guggenheim Fellowship. Professor Tung will combine this with a sabbatical for the 1985-86 year.

STAFF

Joanne Murray, the Departmental Academic Administrator, was one of the recipients of the Murphy award, given by MIT to recognize staff members who have made outstanding contributions, particularly with regard to helping students.

STUDENTS

Three graduate students, Jonathan Buss in applied mathematics and Frederic Bien and It Tan in pure mathematics, were selected to receive three of the 25 Alfred P. Sloan Doctoral Dissertation Fellowships that were awarded nationally in this second year of the program.

ARTHUR P. MATTUCK
In spite of financial stringencies during the past year, all major research programs in the Department have remained active and successful 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.

With regard to the latter, it has maintained a relatively constant credit units per faculty member as well as a relatively stable total of physics students, graduate and undergraduate, over the past 10 years. In this year the number of undergraduate majors was 220, and the number of graduate students was 299. The number of degrees awarded totaled 67 B.S., 6 M.S., and 48 Ph.D.

The large number of graduate students reflects the substantial research funding which the Physics Department Faculty has continued to receive, mostly from the Department of Energy (DOE), National Science Foundation, National Aeronautics and Space Administration (NASA), and the Department of Defense. This has been particularly gratifying in view of the financial limitations which have been placed on these agencies with regard to the funding of basic research.

The Department continues to undertake educational initiatives. To augment the educational and career opportunities for physics students, we have initiated a new physics option: VIIIA Physics with Electrical Engineering. Students in this program fulfill all requirements in Physics, and in addition complete a major portion of the requirements for a B.S. Degree in Electrical Engineering. Successful completion of this program will be certified by a letter signed by the two Department Heads.

We have made use of the opportunities offered by Project Athena to inaugurate a pilot project for a freshman physics laboratory in which computers are an integral part of an experiment: in data acquisition, data fitting, and error analysis. We have also introduced a new undergraduate elective: 8.22 Computational Physics, in which students acquire the techniques to solve a broad range of problems from classical, quantum, and statistical mechanics.

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, Bates Linear Accelerator (BLA), Center for Space Research, Center for Materials Science and Engineering, National Magnet Laboratory, Spectroscopy Laboratory, and Plasma Fusion Center are members of the Physics Department.

In 1984-85 the total number of the Faculty was 88. The following members of the Faculty received promotions during the year: to associate professor with tenure, Robert Redwine; to associate professor, John Dreher. Two new assistant professors joined our Faculty: Stephan Meyer and Jean-Pierre Revol. One faculty member, Carlisle Barber, retired.

Faculty on leaves or sabbaticals during the year included Professors George Bekefi, Robert Birgeneau, Herbert Bridge, Bernard Burke, Walter Lewin, Stanislaw Olbert, David Pritchard, and James Young.

Faculty Sloan Fellows included Professors Charles Alcock, Nihat Berker, Edward Farhi, and Alan Guth. Professor Bruno Rossi was co-recipient of the National Medal of Science. Other awards and honors received by Physics Faculty were the following: Professor Philip Morrison received the James R. Killian, Jr. Faculty Award. Professor Anthony French was elected President of the American Association of Physics Teachers; Professor George Clark was awarded the Breene M. Kerr Professorship; Professor Bruno Coppi was elected a Fellow of the American Association for the Advancement of Science; Professor Bernard Feld received the 1985 Szilard Peace Award (Council for a Livable World); Professor Michael Feld was elected a Fellow of The American Physical Society; Professor Arthur Kerman received a Humboldt US Senior Scientist Award; Professor Miklos Porkolab was co-recipient of the 1984 Excellence in Plasma Physics Award; Professor Victor Weisskopf received an honorary degree from the University of Graz, Austria.

The Physics Faculty established The Herman Feshbach Lectures in Physics, an annual distinguished lecture series.

With regard to student awards, 20 students were inducted this year into Sigma Pi Sigma, the physics honor society associated with the National Society of Physics Students, operated under the auspices of the American Institute of Physics. Also, five students were elected to Phi Beta Kappa: Brent Foy, Margaret Hirlinger, David Montano, Gregory Tucker, Wei-min Wang. 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 Margaret Hirlinger and Corbin Covault. Margaret Hirlinger also was co-recipient of the Association of MIT Alumnae Award. Patrice Parris received the Class of 1948 Award.
Astrophysics research in the Physics Department includes observational and theoretical studies of a broad range of phenomena in the Solar System, in the Galaxy, and in extragalactic space out to the most distant detectable quasars and the remnant radiation from the Big Bang. Observational investigations are carried out in all regions of the electromagnetic spectrum from ground- and space-based observatories. Direct measurements of the interplanetary plasma are made with space probes. Several projects are underway for the development of major new facilities for X-ray, optical, radio, and gravitational wave astronomy.

1. Gamma-Ray Astronomy. The first of two wide-angle "Explosive Transient Cameras" for the detection of brief outbursts of light from peculiar stars has been completed and installed at the Kitt Peak National Observatory. Such outbursts, lasting for a few minutes or possibly much less, are known to be emitted by some of the sources of gamma-ray bursts that have been detected in satellite experiments. The primary purpose of the facility is to locate and identify these sources. In addition, the facility will open a wide new range of astronomical parameter space to exploration.

2. X-Ray Astronomy. Research based on the use of archival data from the MIT focal plane crystal spectrometer on the Einstein X-Ray Observatory (HEAO-2) has yielded a more precise measurement of the total oxygen abundance in the interstellar medium. The result, derived from an analysis of the oxygen K-edge absorption line in the spectrum of the Crab Nebula, is close to the oxygen abundance in the solar system. Other studies using Einstein Observatory data have yielded a survey of the X-ray properties of quasars, and new insights into the composition and physical conditions of the hot X-ray-emitting gas in clusters of galaxies.

An investigation of low-mass binary X-ray sources, carried out with the European X-Ray Astronomy Satellite (EXOSAT) Observatory of the European Space Agency in collaboration with European investigators, has discovered a new kind of quasi-periodic small amplitude variability with frequencies that vary over a typical range of 30 to 50 Hz. The characteristics of this unexpected phenomenon point to an origin of the variability in the interaction between the magnetosphere of a rapidly rotating neutron star and the inner edge of its accretion disk. The discovery has opened a promising new approach to the study of plasma dynamics in accretion-powered X-ray sources.

Three major instrument development projects for future X-ray satellite facilities are progressing through their design definition phases. MIT is one of three institutions selected for participation in the X-Ray Timing Explorer Project (XTE) and is responsible for development of the all-sky survey instrument and for the data system. The XTE will be used primarily in the study of the variability of compact galactic X-ray sources. During the past year MIT was selected for major roles in the development of two of the focal plane instruments for the Advanced X-Ray Astrophysics Facility which will be launched by NASA in the early 1990's. Primary responsibility has been assigned to MIT for the Bragg reflection high-resolution spectrometer, and subsidiary responsibility has been assigned for the charge-coupled device imaging spectrometer.

3. Gravitational Radiation. The 1.5 meter prototype interferometric gravitational wave antenna has been used in continuous data taking to set limits on the flux of impulsive and periodic gravitational wave sources. The strain sensitivity at frequencies above 3 KHz is 2 x 10^-17 strain/Hz^(1/2). Instrument development is continuing to improve the performance to a level of 10^-18 strain/Hz^(1/2) over the 100 Hz to 10 KHz band.

The Caltech/MIT joint project to design, construct, and operate a pair of long baseline gravitational wave antennae is progressing. A project office has been established at Caltech. Two sites, one in Maine and the other in California, have been chosen as primary locations for the 5 Km baseline interferometers.

4. Observational Cosmology. Work continues on the data analysis system for the Cosmic Background Explorer Mission (COBE). The mission is now scheduled to fly in early 1988 and will perform measurements of the spectrum and large-scale angular distribution of cosmic background radiation. The COBE will also measure the diffuse infrared radiation in the wavelength range from 1 to 300 microns.

A new balloon-borne instrument to measure the anisotropy of the cosmic background radiation is under construction. The experiment is expected to fly in 1986 and will search for anisotropies of a few parts in 10^5 in two bands embracing the black-body peak. A second pair of channels will measure the emission by interstellar dust. The instrument uses a single beam to scan the sky rather than a differenced pair of beams employed in prior experiments.

5. Radio Astronomy. The Radio Astronomy Group is pursuing its collaborative search for the optical counterparts of radio sources discovered in the deep survey which they have been carrying out over the past several years. Detailed studies are being made of several interesting objects found in the survey, including the gravitational-lensed multiple-image quasar 0957 + 561 discovered last year and two new ones. The lensed quasars are being used as probes of the large-scale distribution of matter in the universe. VLBI observations of a sample of radio sources showing sub-arcsecond structure are being analyzed for evidence of
gravitational lensing on a sub-arcsecond scale. Theoretical calculations indicate that lensing by single
galaxies should produce many examples of multiple images with such small separations.

6. Optical Astronomy. Simultaneous radial velocity and photometric measurements have been made of the
low-mass binary star system identified as the faint optical counterpart of the X-ray nova A0620-00. An
X-ray outburst of this object was studied by the MIT X-ray Satellite SAS-3 in 1975, and the optical counter-
part was identified at that time on the basis of an accurate X-ray position measured with SAS-3. The recent
observations reveal the properties of the nuclear-burning companion of the compact object which produced the
outburst of X-rays during an episode of mass transfer and accretion.

The systematic 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 yielded 20 new identifi-
cations in the course of the past year. The identified sources include active galactic nuclei, cataclysmic
variables, Be stars, and other interesting and comparatively rare objects that can now be studied in greater
detail with the analytical methods of optical and radio astronomy. The search is being conducted with the
telescopes in both the Northern and Southern Hemispheres and includes extensive collaboration with The
Australian National University.

The 1.3 meter telescope at the McGraw-Hill Observatory has been used in a variety of investigations that
include the study of faint concentric shells of stars found around some elliptical galaxies, observations
of accretion flows in giant elliptical galaxies, and spectrometry of X-ray luminous active galactic nuclei.

The 2.4 meter telescope, being developed jointly with The University of Michigan and Dartmouth College at a
site next to McGraw-Hill Observatory, is nearing completion and is expected to be placed in regular operation
during the fall of 1985.

7. Space Plasma Physics. Data from the Voyager I and II spacecraft are being used in a collaborative study
of the links between the solar wind and aurora on the plante Uranus. Meanwhile, preparations are intensi-
fying for a study of the plasma environment of Uranus by instruments on Voyager II which will make the first
encounter of a spacecraft with that distant planet in early 1986. Continuing analysis of Voyager data
acquired at Jupiter and Saturn with an improved model of the plasma detector response has led to several
new insights into the plasma phenomena around these giant planets, including a reinterpretation of the
disturbance in the Jovian magnetosphere caused by the moon Ganymede. The latter study was carried out in
collaboration with members of the MIT Plasma Physics Group.

In theoretical plasma research a general formulation has been developed for calculating the plasma waves
radiated by a conducting body moving through a magnetized plasma. This formalism has been used to estimate
the power radiated by a conducting wire connecting the Space Shuttle to a tethered satellite in low orbit.

A theoretical study of the evolution of the solar wind from the solar corona to the Earth has been completed.
A self-consistent solution of the two-fluid plasma equations shows that the heat flux associated with outward
streaming suprathermal electrons is sufficient to drive the solar wind along open field lines beyond 1.5
solar radii.

Ion acceleration in the ionosphere and magnetosphere has been the subject of a theoretical investigation
which showed that the interaction between plasma waves and particles is an efficient mechanism for
supplying low-altitude ions with enough energy for their escape from the ionosphere to the magnetosphere.

8. Theoretical Astrophysics. A model has been developed to explain the unique structure within the Crab
Nebula which appears as a short cylindrical stem in both radio frequency and optical line emission ob-
servations. According to the model the stem is a shadow cast across the initial material flow from the
supernova explosion by a chance interstellar cloud. The observed emission comes from processes at the
interface between the flow and the cloud.

Ongoing studies of the evolution of highly compact binary stellar systems, containing a collapsed star and
having orbital periods as short as 40 minutes, have focused on (a) the nature of the systemic angular mo-
mement losses, with particular emphasis on the emission of gravitational radiation and braking torques via
a magnetic stellar wind, (b) the mass transfer rates that can be attained, and (c) the distribution of
orbital periods. An adaptation of the computational method has also been utilized to carry out the first
numerical evolutionary calculations for very low-mass stars (\( \leq 0.1 M_\odot \)) with ages up to the ages of the
Galaxy. These results have been applied to the newly discovered "brown dwarf" star VB 88.

Theoretical analysis of the long-term stability of very wide and therefore loosely bound binary star
systems in the solar neighborhood have placed significant constraints on the amount of dark matter in the
form of dead stars (neutron stars or black holes) with masses greater than two solar masses. Distant
encounters with such objects would tend to disrupt wide binaries. This work narrows substantially the
range of possible explanations for the "missing mass" problem in the galactic disk which is, perhaps, the
most accessible aspect of the more general problem of the nature of the dark matter which comprises more
than 90 percent of the total mass density of the universe.
A new candidate for the dark matter in the universe is "strange matter", which is a bulk quark phase consisting of roughly equal numbers of up, down, and strange quarks plus a few electrons to maintain charge neutrality. Theory suggests that nuggets of strange matter may have any baryon number in the range from $10^2$ to $10^{14}$, where the lower limit arises from shell effects and the upper limit from gravitational collapse. The density of such nuggets is expected to be approximately nuclear density. It has been argued that this phase may be the true lowest energy state of the hadrons, in which case it is absolutely stable. Normal matter with $A > 10^2$ does not decay into this phase because of the high order weak interactions required. It is possible that most of the baryon number of the universe may have condensed into quark nuggets during the quantum chromodynamics (QCD) phase transition in the early universe, at $T \sim 100$ MeV. Calculations have been made in further development of the inflationary universe model. Detailed investigations of the critical processes may be described with confidence, and the calculations show that only very large lumps, with $A > 10^{53}$, survive this evaporation phase. If the dark matter in the universe is primarily quark matter, it must consist of lumps with $10^{53} < A < 10^{57}$ (between 0.1 Jupiter masses and one solar mass). Since non-cosmological production rates for these nuggets seem to be negligible, Earth-based searches for strange matter are to be unsuccessful.

A general mathematical formalism has been developed for the application of the second law of thermodynamics to the study of galaxy formation and evolution. The new method provides a test of whether a stellar system in some specified configuration at one time can evolve by dissipationless processes into some other configuration or class of configurations. A restricted version of the method has been applied previously to constrain the mass of any hypothetical pervasive gas of massive neutrinos which might comprise the dark mass in galactic halos.

Applications of elementary particle theory to the study of the very early phases of the Big Bang have been made in further development of the inflationary universe model. Detailed investigations of the critical phase transition by quantum field theory have shown that if inflation occurs in a localized region which is surrounded by a region that does not inflate, then the localized region will split off from the original spacetime to form an isolated closed universe. A black hole is left in the original spacetime but disappears rather quickly through the process of Hawking evaporation.

Atomic, Condensed Matter, and Plasma Physics Division

1. Atomic, Molecular, and Laser Physics. In the past it was believed that an excited atom would always radiate to the ground state by the process called spontaneous emission. In principle, however, by putting an atom in a cavity its spontaneous emission can be "turned off", creating a fundamentally new type of atomic state: a stable excited state. This idea has now been experimentally realized; initial measurements indicate that the lifetime can be at least 10 times as long as in free space.

Efforts are underway to trap a single charged atom in a magnetic field. This will make possible ultrasensitive mass measurements using cyclotron resonance.

New aspects of quantum transport phenomena in atomic and molecular vapors have been investigated using laser photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no classical analog. Results include measurements of (a) two-level optical radiator collision-induced velocity changes with a few cm/s resolution; (b) magnetic state scattering for isolated multipole moments; (c) resolution of velocity changes accompanying collision-induced molecular radiator reorientation.

Two-level optical superfiancescence (SF) studies have demonstrated that coherent ringing is an intrinsic property of SF in extended samples, resolving a long standing controversy. New measurements of SF in a cavity currently are in progress to study quantum fluctuations in a single longitudinal and transverse mode of the optical field in a cavity, and the SF quantum initiation process.

Biomedical studies are in progress to develop a new type of catheter for "laser angiosurgery", the removal of atherosclerotic plaque by means of laser light delivered via optical fibers. A theory has been developed to model thermal laser ablation; the results agree with dosimetric experiments in human cadaver arteries. In addition, a spectroscopic method for distinguishing normal artery from plaque based on laser-induced fluorescence has been developed. This will make possible in vivo imaging of coronary artery disease.

Laser-induced nuclear orientation has been successfully applied in a table top experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short-lived (lus)$^{53m}$Hf atoms. Values for the nuclear magnetic moment and isomer shift have been obtained. The lifetime of this nucleus is a thousand times shorter than that of any previously studied by optical methods. Present experiments to obtain sub-Doppler narrow gamma resonances are in progress.

2. Condensed Matter Physics. Neutron and X-ray diffraction are being used to study the growth, layer by layer, of molecular crystals on graphite substrates. Two extremal situations are realized by the species xenon and ethylene, respectively, at low temperatures; the former forms thick crystals while only one layer of the latter will coat graphite. The behavior of mixtures of xenon and ethylene have also been studied.
For one monolayer of xenon and varying amounts of ethylene it is found that xenon plates the graphite and completely blocks the ethylene from adsorbing on the surface. Above 70 K the ethylene and xenon mix and a two-layer mixed crystal film is formed. This is the beginning of a major effort to examine the physics of solid-solid wetting and crystal growth at surfaces; that is, epitaxy.

There has been theoretical and experimental progress in elucidating new quantum-mechanical transport phenomena in one-dimensional electronic devices fabricated in the Submicron Structures Laboratory of Electrical Engineering and Computer Science. At low temperatures these semiconductor devices display unusual behavior which indicates that the current through them is limited by a single microscopic quantum state. The conduction process has been successfully described by one-dimensional hopping in a random system. Predictions have been made about the unusual statistical behavior of such a system. In particular, the results of the calculations suggest that the system is not self-averaging as the length grows. A completely different phenomenon is observed at high electron concentration which is, apparently, not a result of reduced dimensionality. Fluctuations in the conductance have been observed as a function of chemical potential (Fermi energy) and magnetic field. Theoretical work suggests that these are the result of quantum interference effects in disordered conductors. The most important theoretical prediction is that all systems, no matter how large and no matter what dimensionality, will have fluctuations in their conductance of order e^2/h. So far, all results agree with the prediction.

Several faculty members have begun research to study the properties of mixtures of molecules which form microemulsions, micelles, and structured liquids. These experiments utilize light scattering and small-angle neutron scattering. A new theory has been developed which, for the first time, is capable of explaining quantitatively phenomena associated with second order phase transitions in such self-assembling micellar systems. Important advances have been made in understanding micellar polydispersity and phase diagrams in multicomponent micellar systems by introducing a variational method not previously known in this field. A new class of reagents has been discovered which appears to suppress very effectively cold cataract formation in the bovine lens. MIT has filed a patent application on the use of these reagents.

Theoretical work continues on microscopic statistical mechanical theories for a number of condensed matter systems, including surface-adsorbed systems, spin-glasses and magnets under random fields, and liquid crystals. The most remarkable progress has been made in the latter, where a microscopic theory for re-entrant nematic-smectic-nematic behavior has been developed. The model is based on the competition between orientational and positional molecular orders. Among the recently achieved agreements with experiment are: (a) the quadruply reentrant behavior of certain molecules; (b) the stringent requirement, for this behavior, on the molecular tail length; (c) the relative layer thicknesses in the different smectic segments along the reentrance sequence; (d) the relative specific heat signals at the upper and lower phase transitions.

It has become possible to calculate the total energies of solids with sufficient accuracy to predict structures. These techniques have been applied to the prediction of the stability of defects in amorphous and crystalline semiconductors; of the structure of silicon, germanium, and GaAs surfaces; and to the migration of defects in silicon. The most novel use of this approach has been to calculate coupling constants between spins on surfaces which are then used as input to predict the thermodynamic properties of the magnetic system.

Studies are underway of GaAs/GaAlAs quantum wells. Using selective pulsed laser excitation from 10 to 100 kW/cm^2 in multiple quantum wells, a new luminescence feature has been discovered below the lowest exciton state. This state has a threshold and shows excitonic character. It is believed to be a many-body quantum state associated with the two-dimensional (2D) character of the quantum well. At high laser excitation levels of 1 MW/cm^2 the formation of the 2D electron-hole plasma has been observed. The experiments indicate that the "Mott Transition" is not sharp and follows the formation of the new excitonic state at lower excitation levels. A quantitative analysis of the Zeeman spectra of ground and excited states of excitons in a single quantum well in Ga_xAl_{1-x}As, using an effective 2D coulomb potential and bulk values of the band parameters of valence and conduction bands, has satisfactorily accounted for all features of this highly complex 2D spectra. Observation of luminescence in modulated doped n-type multiple quantum wells showed oscillatory features which appear to be the formation or shielding of excitons in the presence of electrons. The explanation of this phenomenon is based on the Thomas-Fermi shielding which is resonantly enhanced when the broadened Δ function density of states crosses the Fermi level.

A program to study semiconductors containing large concentrations of ions with large spin, semimagnetic semiconductors, has been very successful. Laser-excited photoluminescence experiments at various magnetic fields suggest the formation of magnetic polarons: a state of an electron, bound to an impurity, whose energy is lowered by exchange coupling to the spins of the magnetic ions. Studies of the magnetic susceptibility show that the ions are randomly distributed which is important for theoretical modeling.

Studies continue on the fundamental wave properties of thermal neutrons and the diffraction physics of neutrons in crystals. Present-day interest in the possible existence of magnetic monopoles (isolated magnetic charges) has led to the consideration of the question of magnetic neutrality of the neutron or, equivalently, the degree of magnetic balance between the magnetic poles of the known magnetic dipole moment. An experiment has been designed and carried out which has led to an upper limit of 10^{-17} for the fractional unbalance which represents about six orders of magnitude increase in sensitivity over that available from
previous observations. Investigations have continued on the coherence characteristics of neutrons while transversing a two-crystal interferometer system. The action of phase-retarding edges and refracting prisms on neutrons passing through a limiting slit placed inside the interferometer has been studied. Theoretical studies have continued on the possible existence of a neutron-spin Pendell"ussung resonance effect in crystals in which the Larmor spin precession length is matched to the Pendell"ussung length in the crystal. An experiment to test this effect is being designed.

3. Plasma Physics. Radio frequency (RF) current drive (use of phased electromagnetic waves to drive toroidal current) was demonstrated in Versator II and Alcator C tokamaks. There were concomitant studies of the influence of RF current drive on plasma stability and transport properties. Significant progress has been made in the past year in several experiments which have taken advantage of the newly upgraded capabilities of Versator II, including the ability to run fully RF driven plasmas without ohmic heating. With a new 100 kW RF system operating at 2.45 GHz, fully RF driven plasmas have been achieved at densities at high as $n = 1 \times 10^{13} \text{cm}^{-3}$ substantially exceeding the 800 MHz density limit, and current drive effects are observed up to $n = 2.5 \times 10^{13} \text{cm}^{-3}$. The possibility that non-linear parametric decay instabilities prevent the wave power from reaching the center of the plasma above the density limit is being investigated.

The propagation and absorption of lower-hybrid waves in toroidal plasmas has been the subject of several experiments on Versator II. A microwave scattering diagnostic has been used to detect the externally launched 800 MHz lower-hybrid waves in the current drive regime.

Ongoing experiments are investigating possible changes in the energy confinement time, in the improved confinement regime, and in fully RF driven plasmas. The needed electron temperature measurements are made with a ruby laser Thompson scattering apparatus capable of temperature measurements at seven radial locations. Further experiments attempting to identify the physical mechanism responsible for the improved confinement behavior are underway using magnetic probes.

In 1985 construction of a new electron-cyclotron resonance heating (ECRH) system began. The ECRH experiment, which is a collaborative effort with the Naval Research Laboratory (NRL), employs a gyrotron power source currently under construction at NRL. The gyrotron will operate at a frequency of 35 GHz at a power level of 150 kW. The design of the transmission system and antenna are being carried out at MIT. The aim of these experiments is to test heating and current-drive processes using RF power near the lower-hybrid frequency and the electron-cyclotron frequency. Also under construction is a new current drive experiment which will employ the fast lower-hybrid wave at 800 MHz.

There has been extensive theoretical and experimental development of novel free electron laser concepts. In particular, a high-power (1 MW), tunable (8-20 GHz) free electron laser operating at record-high efficiencies (-12 percent) was demonstrated. The design of a 1-10 micron wavelength tunable free electron laser to be constructed on the MIT campus is in progress. The facility will include a novel electromagnetic wiggler comprised of a standing electromagnetic wave trapped in a resonant cavity, and energized by high power millimeter wavelength gyrotrons.

Values of Lawson Parameter in the range $n_\tau_T = 0.6-0.8 \times 10^{14} \text{cm}^{-3}\text{-sec}$ were achieved on Alcator C. This exceeds the minimum value required for fusion energy breakeven at higher temperatures in a D-T plasma. Detailed investigations have been made of plasma confinement properties under these extraordinary conditions.

Nuclear Physics Division

The research in this Division is divided into three areas: Experimental Heavy-Ion Physics; Experimental Intermediate Energy Physics, and Experimental Particle Physics.

1. Experimental Heavy-Ion Physics. Heavy ion physics is the study of nuclear structure and reaction mechanisms using beams of energetic heavy ions. Heavy ion reactions are particularly well-suited for the study of the properties of nuclei at high angular momentum and high excitation with the added feature of enabling the investigation of these properties for nuclear species far removed from the stable nuclei found in nature. For more than a decade, the Heavy-Ion Group has been studying these phenomena. Extensive investigations have been carried out on nuclear molecules, extremely high angular momenta, the mechanisms of fusion and induced fission, and searches for super heavy elements. These studies are now ending as the Heavy-Ion Group changes its direction to make use of the relativistic heavy ions which will soon become available at Brookhaven National Laboratory (BNL). In late 1986 they expect to do experiments, in collaboration with groups at BNL, Berkeley, and Tokyo, with beams of 480 GeV sulphur nuclei. The investigations will be into unknown regions of extremely high energy and matter densities equivalent to those at a very early stage of the expanding universe. This new energy regime for heavy-ion reactions may possibly yield indications of a new state of matter, a quark-gluon plasma. The Group is presently building apparatus for this experimental program.

2. Experimental Intermediate Energy Physics. The principal activity in this field is centered at BLa, which functions under the direction of Professor Ernest J. Moniz. This accelerator has become a national facility for intermediate energy nuclear physics, where a major experimental program is underway to study the
properties of the atomic nucleus, using intermediate energy electrons and photons to generate a wide variety of reactions. MIT faculty and Bates staff physicists, and some 125 user physicists (111 domestic, 14 foreign) from 37 other universities and laboratories in the US, Canada, Japan, and Europe are presently engaged as initiators or collaborators in active experiments. Twenty-eight MIT graduate students were associated (during the past year) with the intermediate energy nuclear physics programs.

The Bates intermediate energy program continues to center about the electron-scattering experiments which use the very high precision energy-loss spectrometer. This unique spectrometer facility is being utilized to address a variety of fundamental questions in the structure of atomic nuclei, including the shape and collective motions of heavy deformed nuclei, the electromagnetic structure of few-body systems, and the role of mesons in determining the short-range structure of nuclei. Many of these experiments have been made possible by the increase in the maximum beam energy to 750 MeV by beam recirculation; the maximum energy is now being increased to 850 MeV, with a further increase to one GeV anticipated next year.

A major program of studies characterized by large energy transfer to the nucleus is underway in the second experimental hall. This program, involving the electromagnetic production of pions and/or emission of energetic nucleons, has been made possible by the completion of three large-acceptance magnetic spectrometers and a neutral-pion spectrometer. These studies address issues associated with the fundamental understanding of nuclear reactions and of the nuclear force.

A polarized electron source, built in collaboration with Yale University physicists, is under construction at Bates. This will be used first in a unique test of the unified theory of electromagnetic and weak interactions and subsequently in a variety of nuclear studies. The purpose here is to design plans for the Laboratory center on construction of a pulse stretcher ring to provide continuous electron beams. Building upon previous developments, this upgrade will provide important new research opportunities through intermediate energy coincidence studies. A proposal for an upgrade to a one GeV continuous electron beam facility has been submitted to DOE.

Complementary to the Bates experiments are investigations by the MIT Group at other accelerator facilities. A program of studies of pion-induced reactions, such as charge-exchange and absorption, at the Los Alamos Meson Physics Facility is directed at obtaining a good understanding of pion-nucleus interactions. Other investigations at Los Alamos, at the Indiana University Cyclotron Facility, and at Bates have been crucial for making efficient use of the complementary nature of nuclear probes.

Another Group in Intermediate-Energy Physics is collaborating with physicists at BNL in a study of hypernuclei using a separated K meson beam in order to investigate the binding of \( \Lambda^0 \) and \( \Sigma^+ \) particles in nuclear matter. Data have been obtained which have allowed detailed comparisons with nuclear model calculations. This Group is also exploring jointly with physicists at Bell Laboratories the feasibility of constructing a detector which will measure both the flux and spectrum of low-energy solar neutrinos.

3. Experimental Particle Physics. This area consists of the Accelerator Physics Collaboration Group, the Counter Spark Chamber Group, and the Electromagnetic Interactions Group.

a. Accelerator Physics Collaboration Group. This Group is conducting experimental research on the nature and interactions of photons, hadrons, and neutrinos at two of the country's national accelerator laboratories, the Stanford Linear Accelerator Center (SLAC) in California and the Fermi National Accelerator Laboratory (FNAL) in Illinois. In the Stanford experiment the goal is to study the photoproduction of vector mesons containing charm.

An experiment at FNAL, presently being analyzed, was designed to study hadron production from hydrogen and heavier nuclei. For this study a unique device was developed that identifies each particle produced. The device, called CRISIS, worked well and will provide unique information. A number of the results from this experiment have already been published, and work is continuing on the hadron production from nuclei. This topic is of interest, not only for high energy physics, but also in the understanding of reactions in relativistic heavy-ion physics.

Apparatus is now being designed and built for an experiment that has been approved for running at FNAL in 1986. The goal of the experiment is to search for a proposed but undiscovered particle, the \( \tau \) neutrino. Proof or non-verification of its existence will have major theoretical consequences. This experiment will use a new technique being developed explicitly for it, holographic bubble chamber photography. The technique will provide a factor of 10 improvement in resolution over conventional bubble chamber photography. The chamber has been built and is operating, meeting all of its specifications.

The Group is presently taking data at FNAL in the world's highest energy neutrino beam. This experiment, which is using the holographic bubble chamber which was designed for the \( \tau \) neutrino experiment will be looking at a new domain in neutrino physics.

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 Accelerator Physics Collaboration Group has been the organizer of the FNAL experiments and of the consortium.
b. Counter Spark Chamber (CSC) Group. The CSC Group is involved in a Fermi-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 last year 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 is presently continuing its neutrino studies with Tevatron II, the Fermilab 1000 GeV accelerator. The major objective of the first experiment in this program is the study of the "like sign" dimuon process, which presently is not understood.

In addition the Group has recently entered into two other major collaborative programs. (1) The use of μ mesons at the Tevatron to study nucleon structure and the mechanisms of particle production. The Group is participating in the construction of a spectrometer to be used in these studies. (2) The use of 50 GeV e^+e^- colliding linac beams (SLC) at SLAC to investigate the physics of the intermediate vector boson Z^0. The collaboration is now constructing an advanced detector called SLD, which would 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 Z^0, and for processes involving heavy quarks with hitherto undiscovered flavors, in addition to investigating the decay channels of the Z^0.

c. Electromagnetic Interactions Group. The Group is engaged in two efforts in experimental high-energy physics: one at the presently highest energy electron-positron colliding beam accelerator, PETRA, in Hamburg, Germany, and the other at the newly-approved 100 GeV electron-positron accelerator, LEP, in Geneva.

The work at PETRA: After its discovery of gluons, this Group has concentrated on the study of 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, and they have also made precision measurements of the interference of the exchange of the photon and the Z^0 in muon pair production and found the results to be in agreement with the W-S-G theory. 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 plans to continue to take data to search for new types of electrons and new, heavier quarks.

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 end of 1988. The purpose of this experiment is to understand the properties of Z^0 boson and to search for the Higgs particle, heavy quarks, and heavy leptons.

Theoretical Physics Division

1. Particle Physics. The "standard theories" of the interaction of quarks and leptons through gauge fields, QCD for the strong interactions, the W-S-G theory for the electromagnetic and weak interactions and general relativity for gravitational interactions 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? The most elegant and simple "grand unification" of strong, electromagnetic, and weak seems to fail the experimental test by predicting an unobserved rate of proton decay, but more complex schemes exist, and form the basis of scenarios of the development of the very early universe. The Particle Theory Group is a leading group in the study of these "inflationary universes" which has now reached the stage of detailed confrontation with the known facts about later development of the cosmos. The apparent paradoxes which arise in the dynamics of a bubble of metastable vacuum surrounded by true vacuum have been resolved in a simple and beautiful picture. In another investigation on the frontier of particle physics and astrophysics they have studied whether "strange matter" with a different quark composition from ordinary nuclear matter could be stable and could have survived from its formation in the early universe. The most likely "strange" objects seem to be star-size. Data from a laboratory search proposed by them in which meteoritic matter was bombarded with gold ions is being analyzed.

Last year the first hints appeared in experimental results from CERN (European Organization for Nuclear Research) of clues to what may lie beyond "standard" theory. The Group has put much effort into analyzing the evidence and trying possible theoretical explanations. In particular, an alternative to the standard theory with a subtle dynamics is being explored in depth. Even within the standard theory a whole range of fundamental dynamical questions remains to be resolved, and this continues to be an active area of research with many diverse approaches ranging from traditional field theory to the construction of special purpose array processors for numerical simulations of QCD. This merges with the interest of the Nuclear Theory Group in the role of quark-gluon degrees of freedom in nuclear collisions.
The study of the structures implicit in quantum field theory continues to reveal rich possibilities. The Group has pursued a new way of understanding many of these structures in terms of mathematical "co-cycles" and developed and applied them in contexts ranging from the Hall effect to gravitational theory. They are actively working on supersymmetric field theory on curved space, a subject which ties in with some of the most exciting speculation on unification.

2. Nuclear Theory. An area of fundamental interest is the role of underlying quark and gluon degrees of freedom in the nucleon, in nucleon-nucleon interactions, and in nuclear structure. Although it is believed that the structure and interactions of hadrons are governed by QCD, there is as yet no quantitative theory of even the most basic questions: how do we understand the properties of a nucleon in free space, how is a nucleon altered when it is embedded inside a nucleus, and why is low-energy nuclear physics so little affected by the internal structures of nucleons? These questions are being approached both from the perspective of lattice gauge theory, and in the context of non-relativistic quark models. Studies of nuclear matter have focused on the clustering of quarks into nucleons and the experimental signature of non-nucleonic degrees of freedom. Hadron-hadron interactions have been studied in both the non-relativistic quark model and in the MIT bag model. A major new initiative has been undertaken in investigating the collisions of relativistic heavy ions, including study of the properties, evolution, and hadronization of the quark gluon plasma, understanding particle multiplicities, and seeking experimental signatures of new physical phenomena.

Nuclear many-body theory provides the foundation for many facets of nuclear theory and has therefore been an area of continuing interest. The success of relativistic models of nucleon-nucleus scattering has motivated continued efforts in the study of relativistic many-body theory. Recent developments in functional, integral, and stochastic methods have proven fruitful in a variety of applications, ranging from problems in traditional nuclear structure to the study of relativistic nuclear models and field theory. Progress has continued in the theory of nuclear collective motion, utilizing both time-dependent perturbation theory and the Born-Oppenheimer approximation.

Electromagnetic interactions have been a long-standing focus of theoretical interest in the Group, both by virtue of the unique precision of the probe and the commitment to the experimental program in electron scattering at the MIT Bates Linac. A detailed study has been made of the additional nuclear structure which is revealed by studies with polarized electron beams with polarized targets and by coincidence experiments. The structure of the electromagnetic current operator in nuclei is being studied, both from the prospective of meson exchange currents and quark substructure.
Cell Culture Center

The Cell Culture Center at MIT was established by the Human Biology Program of the National Science Foundation (NSF). Its purpose is to serve as a facility and resource for all biologists throughout the United States. The Center is currently funded by both the NSF and the National Institutes of Health (NIH).

The Center is headed by Professor Phillips W. Robbins, Principal Investigator and Donald J. Giard, Director. The mission of the Center is to produce cells and viruses on a large scale in order to allow scientists to conduct novel and important experiments in basic cell biology 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 techniques for large-scale cell and virus production.

Production

During the period July 1, 1984 to June 30, 1985, the Cell Culture Center provided animal cells and their products to 46 research projects throughout the United States. Cells are routinely produced either in suspension culture or as roller bottle (RB) cultures. During this period, the demand for suspension culture continued to increase over the preceding years. Approximately \(10^{13}\) cells were produced. Examples of projects completed during the past year include:
- 227 liters of conditioned media from BRL-3A cells for Syracuse University, Syracuse, New York.
- 720 RB of SV-80 cells for the University of Illinois, Urbana, Illinois.
- 100 liters of AMA-1 cells for MIT, Cambridge, Massachusetts.
- 340 liters of RBL-1 cells for Harvard Medical School, Boston, Massachusetts.
- 200 liters of MOSER cells for Baylor College of Medicine, Houston, Texas.
- 200 liters of HeLa cells for the University of Toronto, Toronto, Canada.

Cost Apportioning Program

The Center recovers a substantial part of its total operating costs through a user charge known as the Cost-Apportioning Program. Under this program, users are required to pay for all expendable materials and services as well as some of the labor costs. The Center receives almost 100 percent return on all materials, services, and labor costs billed. The balance of operating funds is obtained primarily through grants from the NSF and the NIH.

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 cell 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 have insufficient resources and equipment in their own laboratories for using this type of specialized technique.

The laboratory offers many options for cell analysis and separation including:
1) immunofluorescence assays using direct or indirect antibodies labeled with fluorescein or rhodamine and phycoerythrin;
2) DNA analysis using a variety of stains such as propidium iodide, DAPI, ethidium bromide and mitramycin;
3) membrane potential using several classes of synanin dyes;
4) sorting on the basis of light scattering parameters as a measure of cell complexity and development;
5) cell and nucleus diameter by measurement of axial light pulse width and fluorescence width;
6) DNA/RNA ratio;
7) simultaneous immunoassays and DNA content using propidium iodide and specific antibodies.

During the past year, the Cell Sorter Laboratory completed 26 approved projects. The demand for its services has steadily increased, and currently the laboratory is involved in projects representing a wide range of the various applications described.

Research and Development

Our Research and Development effort, which is supported entirely by separate research grants, continues to be a very important aspect of the Center's operations. To date, the Center's research has focused on the development and improvement of the microcarrier system for growing anchorage-dependent cells, and an examination of its many applications. In the past year, emphasis has been placed on the following
projects:
2) A Dynamic Approach to Protein Purification by Adsorption.

The objective of the first project is to develop principles for optimizing and controlling fed-batch cultures of mammalian cells. Progress has been made in this project in the following areas:

1) Developing equations that accurately describe the cellular kinetics as a function of the environment.
2) Incorporating these equations into a fed-batch process model for the purpose of minimizing production costs.
3) Performing a sensitivity analysis with respect to the model parameters to identify the critical elements of the system.

The basic objective of the second project has been to study a novel method for the separation of proteins and other biological macromolecules from complex mixtures, emphasizing the dynamics of this process. The proposed method involves the adsorption of proteins from solution onto particles of porous absorbent using a staged series of well-stirred batch contactors. This method takes advantage of the phenomena of restricted diffusion and equilibrium partitioning of large molecules in pores only slightly larger than the diffusing molecules. During the past year, the following were achieved:

1) The concept of an optimum contact time for maximizing the purification of a desired species both experimentally and by mathematical simulation, has been demonstrated.
2) The usefulness of the above approach has been verified through its application to the recovery of human gamma interferon from spent cell culture medium containing fetal bovine serum.

Projects from July 1, 1984 to June 30, 1985. (46 investigators)

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DONALD J. GIARD
The academic year 1984-1985 has been one of transition for the Center for Cancer Research. Professor Salvador Luria, the Director of the Center since its establishment in 1972, retired and Professor Phillip Sharp assumed the Directorship. In addition, three faculty members from the Center, Professors David Baltimore, Robert Weinberg, and Richard Mulligan, moved to the new Whitehead Institute during this year. Two new young faculty members were appointed in the Center, Professor Earl Ruley, who is interested in the collaboration of oncogenes in malignant transformation, and Professor Brent Cochran, who is studying the activity of a hormone peptide encoded by an oncogene on cellular growth control. Another academic change for the Center faculty was the promotion of Professor David Housman to Full Professor.

Research in the Center made significant progress in 1984-1985. Particularly noteworthy was the identification of genes encoding proteins that form part of the antigen receptors on the surface of T lymphocytes, by Professor Susumu Tonegawa. Important insights into the biological role of these particular receptor proteins emerged from a collaboration of three immunology laboratories in the Center, those of Professors Tonegawa, Herman Eisen, and David Raulet.

The research and teaching excellence of the Center's faculty has been recognized in several ways this year. Both of the new faculty members, Professors Ruley and Cochran, received Rita Allen Foundation Scholar Awards. Professor Tonegawa's contributions to the molecular genetics of the immune response was further recognized by the "Order of Culture" award from the Japanese Government. Professor Sharp received the Howard Taylor Ricketts Award from the University of Chicago for his research on splicing of RNA.

The Center had a number of faculty-rank visitors during the academic year: Professor Hara Ghosh, Chairman of Biochemistry, McMaster University; Professor David Shapiro, University of Illinois; Professor Lee Adair, University of South Florida; Dr. Mark Fasternack, Assistant Professor, Harvard Medical School, and Dr. Judah Weinberger, Assistant Professor, Harvard Medical School.

The faculty of the Center teach in graduate and undergraduate courses in Biology as well as train graduate students. During the academic year five students received Ph.D. degrees from the laboratories in the Center. In addition, the Center's faculty members also train future scientists at the postdoctoral level; in total, there are 47 such individuals in the Center, the vast majority of whom are supported by competitive fellowships. Noteworthy in this group is Dr. Bradley Sheares, who received one of the first Markey Scholar Awards. We had an occasion this year to catalog past fellows now holding faculty appointments who were trained in the Center since its founding; the list included 55 entries as of 1984.

PHILLIP A. SHARP
Center for Space Research

The Center for Space Research (CSR) conducts an active program of research in space science and technology, with emphasis on experimental and theoretical investigations in support of various NASA missions. Although the primary source of support is from NASA, a substantial fraction of the research program is sponsored by the NSF and DOD. Specific areas of research include X-ray astronomy, planetary magnetospheric and interplanetary space plasma physics, the life sciences, properties of planetary surfaces and atmospheres, the detection of gravity waves, and optical and radio astronomy. A major part of this program concerns the analysis and interpretation of data from flight experiments carried out in these areas. The current long-range NASA flight program includes several missions in which MIT and the Center are heavily involved. Among these are the Venus Radar Mapper (VRM), the Mars Observer (MO), the Advanced X-ray Astrophysics Facility (AXAF), a large area X-ray Timing Experiment (XTE), and a large-scale investigation of the plasma environment of the earth as part of the International Solar Terrestrial Physics Program (ISTP). The Center also supports a program in theoretical astrophysics and a program of optical investigations 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 archives of data obtained during the period from 1975 to 1980 using the MIT X-ray instruments carried aboard the Small Astronomical Satellite (SAS-3) and High Energy Astrophysical Observatories (HEAO-1 and HEAO-2, the latter also called the Einstein Observatory) have continued to provide valuable material for research in high energy astrophysics. Meanwhile, the European X-ray Observatory Satellite (EXOSAT) has been opened to guest observers, and Professors Walter Lewin and Hale Bradt have participated in a number of studies with it. One of these, proposed by Professor Lewin, discovered a new kind of quasi-periodic variability in the X-ray brightness of low-mass X-ray binaries. The phenomenon apparently arises at the interface between the accretion disk and the magnetosphere of a weakly magnetized neutron star, and provides new clues to the nature of the processes that occur in accretion-powered sources.

Analysis of data from the Einstein Observatory has continued under the direction of Professor Claude Canizares. The observed X-ray line emission from supernova remnants and clusters of galaxies has been used to probe the physical conditions in the plasmas of these objects. Studies have been made of X-ray emission from galaxies, clusters of galaxies, active galactic nuclei and quasars. In many cases, supporting optical observations have been carried out at the McGraw-Hill Observatory, a major observatory in Arizona for which MIT (through CSR) provides partial support.

Rocket-Borne X-ray Experiments

During the past several years, the MIT X-ray Astronomy Sounding Rocket Group, under the direction of Professor Saul Rappaport and Dr. Alan Levine, has designed and constructed a new wide-field soft X-ray camera. The instrument features three nested Wolter-Schwarzchild grazing incidence mirrors, and a 35mm-diameter microchannel plate imaging detector at the focal plane. The camera has a 60° field of view and is sensitive over the energy range: 50-250. It was launched successfully on a Black Brant sounding rocket from the White Sands Missile Range on March 18, 1985, yielding data which are presently being analyzed.

Advanced X-ray Astrophysics Facility (AXAF)

In the spring of 1985, NASA announced the selection of the AXAF High-Resolution X-ray Spectroscopy Investigation (HRXS), with Professor Claude Canizares as the Principal Investigator (PI). The investigation involves definition, design, and construction of a Bragg Crystal Spectrometer (BCS) and a Transmission Grating Spectrometer (TGS). The BCS is a next-generation version of the spectrometer built at CSR and flown on the Einstein Observatory, while the TGS uses the unique capabilities of the Submicron Structures Laboratory (SSL) in the Research Laboratory of Electronics, with Professor Henry I. Smith, director of SSL, as a co-investigator (Co-I). Tests of Bragg diffractors, detectors, and grating facets are being carried out in CSR.

An AXAF experiment involving Dr. George R. Ricker as Lead Co-I was also selected. Dr. Ricker has been active within CSR for many years in the application of charge-coupled (solid state) devices (CCD) to astronomical observations at both optical and x-ray wavelengths. This experiment, under the direction of Professor Gordon Garmire of Pennsylvania State University and called the AXAF CCD...
Imaging Spectrometer (ACIS), will yield a spatial resolution of about 0.3 arc second, while simultaneously providing useful resolution in energy. The selection of the HRXS and ACIS experiments provides MIT with a major role in two of the four experiments to be flown on AXAF.

**X-ray Timing Explorer (XTE)**

XTE is a NASA X-ray Astronomy satellite program which has been proposed for launch in the early 1990's; experiments have been selected by NASA but full funding awaits final scheduling and approval of the mission. The main objective is to study the time-variability of celestial X-ray sources on a wide range of time scales ranging from milliseconds to years. A CSR group under Professor Bradt is participating in mission studies and is beginning development of the scientific instrumentation for which MIT has primary responsibility. As part of this program, CSR is conducting laboratory studies of position-sensitive detectors for the Scanning Shadow Cameras, which will serve as all-sky X-ray monitors.

**RESEARCH IN SPACE PLASMA PHYSICS**

**Interplanetary and Magnetospheric Plasmas**

The Space Plasma Physics Group, consisting of Professors John Belcher, Herbert Bridge, and Ralph McNutt, and Dr. Alan Lazarus, continues to process solar wind data from the Voyager-2 spacecraft, now at a distance of 20 A.U. from the sun, and the Interplanetary Monitoring Platform (IMP-8) spacecraft in Earth orbit. IMP-8 is currently the only extant solar wind monitor near Earth, and its data serve as an irreplaceable input both for terrestrial magnetospheric studies and as a reference for the Pioneer and Voyager deep space probes. Planning for the Uranus encounter on January 24, 1986 of Voyager-2 continues. The Group is also participating in mission planning and data analysis for the plasma instrument on the Glotto mission now on its way to Halley's Comet.

General theoretical work in space plasmas has applied the basic kinetic theory of charged particles moving in a magnetized environment to problems in weak and strong plasma turbulence, plasma instabilities and collective effects on wave-particle interactions. The specific phenomena considered in this research include: diffuse, discrete, and flickering aurora; the onset of magnetic substorms; the origin of the auroral kilometric radiation; the formation of non-Maxwellian ion and electron distributions; VLF whistler modes; lower- and upper-hybrid instabilities; the trapping and precipitation of energetic charged particles; plasma processes near the Earth's bow shock; ion conics; and beam-plasma interactions. Drs. Tom Chang and Geoffrey Crew and Professor Stanislaw Olbert are currently involved in this program.

In June, the Plasma Group organized a major specialty conference on ion acceleration in the magnetosphere and ionosphere that was held at Wellesley College.

**PLANETARY STUDIES**

**Venus Radar Mapper (VRM)**

CSR participation in this mission involves Professor Gordon Pettengill, Dr. Peter Ford and Dr. Binsack. Professor Pettengill has played a major role in the overall design of the mission, with Dr. Ford involved primarily in the reduction of altimetric and radiometric information to be obtained from the radar instrument. The VRM mission will be launched in April 1988, and should yield a global map at a resolution of a few hundred meters, sufficient to understand many of the geological and geophysical processes that have shaped the cloud shrouded surface of Venus.

**Mars Observer (MO)**

The MO mission is designed to observe those global aspects of Mars which were given short shrift by the earlier Viking and Mariner spacecraft, specifically a high-quality topographic map and other observations that yield a global picture of that planet's surface composition and geology.

CSR is proposing to participate in several aspects of this NASA-approved mission, primarily in the development of instrumentation for measuring topography (a radar altimeter, jointly with the Jet Propulsion Laboratory) and surface composition (an optical/infrared reflectance spectrometer, jointly with the University of Hawaii).
SEARCH FOR GRAVITY WAVES

A large-scale effort, supported by the National Science Foundation (Physics), to demonstrate the feasibility of an optical interferometer that can detect gravitational radiation has been undertaken by Professor Rainer Weiss and his group. This effort is collaborative with the California Institute of Technology (Professors Ronald Drever and Kip Thorne), and involves the eventual construction of two identical "antennas", one on each coast of the U.S.

The technique involves monitoring the relative displacements of two masses separated by up to 5 km of near vacuum to an accuracy exceeding $10^{-18}$ m in one millisecond. This is accomplished by measuring the phase change in a laser beam that has been reflected 50 times back and forth over the separation. At this level of sensitivity it is considered likely on theoretical grounds that some natural sources of gravitational radiation will be detected.

SPACELAB VESTIBULAR EXPERIMENTS

Professor Laurence Young and Dr. Charles M. Oman have continued to analyze data, obtained in 1983 from the Spacelab-1 (SL-1) shuttle mission, on the ways in which weightlessness affects the functioning of the human inner ear. Similar experiments are planned to fly on the German D-1 and SL-4 Spacelab missions in late 1985 and 1986, respectively.

GORDON H. PETTENGILL
MIT's Clinical Research Center (CRC) was established in 1964 to provide a facility in which MIT investigators and their collaborators could apply the Institute's expertise in basic biochemical and biophysical mechanisms to the analysis of normal and pathophysiological 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 sufficient qualified physicians would be involved in the CRC's activities to enable it to take responsibility for all but acutely-ill subjects. Its research activities have, over the years, involved patients with many types of illnesses (as well as normal volunteers), so long as they were not acutely ill.

For most of its history, the CRC has been located administratively within MIT's Department of Nutrition and Food Science, and its focus has been in nutrition and metabolism. On February 1, 1985, the name of MIT's Department of Nutrition and Food Science was changed to "Department of Applied Biological Sciences", reflecting the diversity in that department's current research interests and its diminished commitment to nutrition. During the past year, the CRC's administrative status has also changed: it is no longer a component of the Department of Applied Biological Sciences, but reports directly to the Dean of the School of Science. This administrative change enhances the CRC's ability to make appointments, sponsor research activities, and develop its own training programs. It also identifies the CRC as the major continuing locus of research in nutrition and metabolism at MIT, and a home for research and training opportunities in such other diverse fields as neuropsychology, clinical neurochemistry, psychopharmacology, and the study of obesity and Alzheimer's Disease.

On June 30, 1985, Professor Nevin Scrimshaw will retire as Program Director and Professor Richard Wurtman will be appointed as the new Director. Professor Wurtman's research interests span the fields now represented at the CRC (and listed above). This appointment reflects MIT's commitment to the continued growth of its CRC along its present intellectual spectrum; ranging from nutrition and metabolism and endocrinology, to brain sciences and behavior. This spectrum of activities has been highly productive; moreover it is consonant with MIT's other Life Science activities.

At present, most of the research activities of the CRC are associated with three clinical areas, and involve three groups of scientists each led, unofficially, by a senior professor. These are: nutrition/metabolism (Professor Vernon R. Young); neurochemistry/neuropsychopharmacology (Professor Richard Wurtman); and human neuropsychology (Professor Suzanne Corkin). Other planned or existing CRC research projects exploit MIT's skills in medical physics and instrumentation (for example programs to improve imaging techniques and to develop new therapies based on irradiations). Each group includes investigators who hold full-time MIT academic or staff appointments (e.g., Professor Nevin Scrimshaw; Dr. Robert Hoerr; Dr. Judith Wurtman; Dr. Harris Lieberman) as well as those holding appointments both at MIT's CRC and at other Boston-area biomedical institutions (e.g., Drs. William Dietz; John Growdon; Jerrold Bernstein; John Burke). Moreover, numerous collaborative studies involve both an MIT professor and one or more investigators at an outside hospital or research laboratory. Although MIT's CRC must justify its existence by its success in facilitating clinical investigations directed by MIT personnel, it also amplifies its scientific contributions by making some of its resources available to talented clinical investigators with appointments at other Boston area institutions, who collaborate with MIT scientists working in areas of mutual interest. Examples of other institutions whose investigators now collaborate with the CRC include: Boston University Hospital, Beth Israel Hospital, Children's Hospital Medical Center, Massachusetts General Hospital, Shriner's Burns Institute and Tufts New England Medical Center.

The intellectual spectrum represented at MIT's CRC may be unique among American clinical research centers, and offers opportunities to carry out research programs that might not be possible were the CRC strong only in, for example, nutrition and metabolism or brain and behavior. One example of such programs is the CRC's numerous protocols involving behavioral, metabolic, or therapeutic aspects of human obesity. Another is the CRC's growing commitment to the understanding and, eventual treatment of, Alzheimer's Disease. The MIT CRC is firmly woven into the fabric of the Massachusetts Alzheimer's Disease Research Center (ADRC), one of five federally funded centers established by the National Institute on Aging in 1984. Dr. John Growdon, the principal investigator of the ADRC, is an attending physician at the CRC and a member of it's Executive Committee. Professor Wurtman is a member of the ADRC Scientific Advisory Board; he is also an attending physician at the MIT CRC and will become the CRC Director. Professor Suzanne Corkin is a member of the ADRC's Executive Committee and Scientific Advisory Board; she is a senior scientist and principal investigator at the MIT CRC. Dr. T. John Rosen is the head of the ADRC's Data Management core and ex-officio member of the Executive Committee; he is a research statistician in the MIT Department of Psychology and supervises data management and analysis for all of Dr. Corkin's research projects conducted at the MIT CRC. Moreover, several of the individual research projects funded by the ADRC will be conducted at the MIT CRC.
Bed utilization at the MIT CRC has averaged 90.8% during the last year, resulting in a total of 3,066 inpatient days. One factor allowing for this high degree of utilization has been the admission of many subjects (especially normal volunteers) for "full days" of at least eight hours, during which time, for example, infusion studies on deuterated amino acids could be carried out without requiring the subjects to remain overnight at the CRC. There were 1,085 visits to the CRC's outpatient facilities.

The CRC now contemplates a major increase in its commitment to providing training, and intends to develop three programs for this purpose: one for post-doctoral physicians (a minority of whom may also take doctoral degrees, perhaps with Professors Young or Wurtman); one for MIT undergraduates in the "UROP" or undergraduate research opportunities program; and one for physicians in the Boston area. Towards these goals, the CRC will appoint a Director of Training.

The CRC will also expand its number of Assistant Program Directors to include five young physician-investigators, instead of only one (as is customary in CRC's located within university hospitals). They include: a neurologist, a psychologist, an internist, and two pediatricians. These investigators have completed both specialty medical training and research training, and would, if they choose, be eligible for a junior faculty position at a medical school. Instead they have elected to work under the "umbrella" of the CRC for three to five years, serving its research and training needs while accumulating the bibliography that presumably will lead to a more senior faculty position when their CRC appointment ends.

A sampling of the major research projects currently underway at the CRC follows:

- Characterization of Subgroups in Alzheimer's Disease, Suzanne Corkin, Ph.D.
- Behavioral Effects of Brain Injury - Cingulotomy for Pain and Psychiatric Disorder, Suzanne Corkin, Ph.D.
- Optimal Dietary Therapy for Obese Adolescents, William H. Dietz, M.D., Ph.D.
- Energy Expenditure in Obese and Non-obese Adolescents, William H. Dietz, M.D., Ph.D.
- Quantitative Glucose Metabolism in Aging Humans, Naomi K. Fukagawa, M.D.
- Brain Neurotransmitters and Human Behavior, John H. Growdon, M.D.
- Gut and Liver Contributions to Whole Body Amino Acid Metabolism, Robert A. Hoerr, M.D.
- Bioavailability of Amino Acids, Robert A. Hoerr, M.D.
- Human Vitamin D in Nutrition in Health and Disease, Michael F. Holick, M.D., Ph.D.
- The Behavioral Effects of Caffeine, Harris R. Lieberman, Ph.D.
- The Effects of Melatonin on Human Behavior, Harris R. Lieberman, Ph.D.
- Nutrient Choice Patterns and the Effects of Nutrients on Behavior Among Young and Old Adults, Judith H. Wurtman, Ph.D.
- Patterns of Food Choice Characteristic of Appetitive Disorders, and the Effects of Tryptophan and D-Fenfluramine, Judith H. Wurtman, Ph.D.
- A Novel Approach for the Study of Human Amino Acid Metabolism in Relation to Dietary Requirements, Vernon R. Young, Ph.D.
- Vitamin A and Beta Carotene Absorption in Adult Men, Vernon R. Young, Ph.D.
- An Investigation of Proline Kinetics and the Regulation of Proline Biosynthesis in Man, Vernon R. Young, Ph.D.
- Selenium Metabolism in Adult Humans, Vernon R. Young, Ph.D.
- Metabolism of Methionine in Healthy Young Men, Vernon R. Young, Ph.D.
- Somatostatin Modification of Hepatic Glucose Output in the Aged, Vernon R. Young, Ph.D.
- Evaluation of Zinc Absorption by Children with Inflammatory Bowel Disease, Vernon R. Young, Ph.D.

RICHARD J. WURTMAN
Experimental Study Group

The Experimental Study Group (ESG) finished its sixteenth year of alternative academic instruction at MIT by receiving the 1985 Irwin Sizer award for having made "the most significant improvement to MIT education." We were very pleased to receive this award and will be using the accompanying stipend which was provided by the Graduate Student Council to support some of the community activities and experimental ventures in teaching and learning which have proved helpful to ESG students and staff members over the years.

Student Statistics

ESG recorded the greatest amount of interest in its history from incoming students this fall. Total figures for the year's enrollment included 50 freshmen (including three sophomore transfer students who took freshman subjects in ESG) and 18 sophomores who had been in ESG as freshmen, with 17 students placed on a waiting list in the fall. Thirty-eight percent of the freshmen were women, 16 percent were international students, and 12 percent were minority students. These figures are higher than the corresponding percentages in the freshman class overall. Forty-nine percent of the ESG freshmen expressed an interest in majoring in engineering and 42 percent in the sciences, compared with 62 percent and 25 percent respectively in the total freshman class at MIT. The main reasons why freshmen joined ESG this fall (as reported on their entry forms for ESG) were: availability of one to one tutoring and individual attention, opportunity for self-paced study, community aspects of ESG, and opportunity for small group instruction. The freshmen completed approximately 52 units each term, taking an average of three subjects in ESG and two subjects in the regular curriculum (primarily in humanities subjects which aren't offered through ESG). Of the 42 sophomores who were in ESG as freshmen achieved a median grade point of 4.1 this year, a figure which is higher than the corresponding figure in the regular curriculum for the fifth consecutive year. Eighteen of these sophomores took an average of 1.4 subjects in ESG each term, usually in a humanities subject or a sophomore level mathematics subject. The graduating seniors who were alumni of ESG earned a median grade point of 4.3, a figure which is higher than the figure for the regular curriculum graduating seniors. Several ESG alumni who graduated this spring won MIT awards, including Erik Devereux (Stewart award) and Donald Kane (Compton award). These students join a series of ESG alumni who have won awards or fellowships from MIT upon graduation in recent years.

Staff and Administration

Professor J. Kim Vandiver, in his first year as Director of ESG, and Holly Sweet, Associate Director, in her eighth year at ESG, oversaw the administration of the program. They were supported by the ESG Faculty Advisory Committee which was chaired by Professor Alan Davison (Department of Chemistry) and included Professor Sy Friedman (Department of Mathematics), Professor Arthur Kaledin (History Section, Department of Humanities), Dr. Alan Lazarus (Department of Physics), and Associate Provost Frank Perkins. Professor John Deutch, Dean of the School of Science, continued to provide fiscal support for ESG.

Professor Vandiver brought with him an agenda which included involving more MIT faculty in ESG. Through a good deal of effort and creative planning, 24 faculty members ended up participating in some aspect of ESG's academic program this year. Professors Davison, Lee Grodzins (Department of Physics), Vandiver (Department of Ocean Engineering), and Professor Emeritus Robert Halfman (Department of Aeronautics and Astronautics, Director of ESG from 1974-1984) taught science subjects in ESG. Professor Gary Marx (Department of Urban Studies and Planning) joined the ESG staff in the fall to teach a new subject in Surveillance and Society. Professor Philip Morrison (Department of Physics) organized a yearlong UROP project on ancient alignments which involved a number of ESG freshmen and sophomores. In addition, 18 other faculty members participated in one or more of the undergraduate seminars which were run at ESG this year.

Other members of the ESG staff included Dr. Peter Dourmashkin and Craig Watkins in physics, Dr. Mark Haiman and graduate students Nicholas Reingold and W. Montgomery McGovern in mathematics, Fanny Howe (Writing Program, Department of Humanities), graduate student Lee Perlman (Department of Political Science), and Ms. Sweet in the humanities and social sciences, and Miguel Mitchell in chemistry. Twenty-seven undergraduate tutors (who had been in ESG as freshmen) continued to enable ESG to provide individualized instruction in the core subjects by shouldering a substantial amount of the one to one teaching responsibilities under staff supervision.
Current Academic Developments

The ESG staff and tutors were quite active in creating new subjects and experimenting with teaching methods throughout the year. Dr. Dourmashkin developed a new undergraduate seminar on the frontiers of scientific research for the fall term. This seminar was so successful at ESG that Dr. Dourmashkin was given funding by the School of Science to repeat it in the regular curriculum for the following term. Professor Vandiver, Dr. Dourmashkin, and Ms. Sweet collaborated in developing a new undergraduate seminar for ESG on the role of the modern engineer in the spring term. This seminar focused on an autobiographical look at the personal and professional lives of a variety of engineers. Because of its popularity and its relevance to freshmen who may be in the midst of choosing a career, it will be repeated at ESG in the coming year.

Several other new subjects were organized at ESG this year: a seminar on numbers and arithmetic run by Dr. Haiman and Mr. Reingold, a course on mathematical physics taught by Dr. Dourmashkin, a combined 18.02 Calculus and 8.02 Physics II course organized by Mr. Reingold and Richard Singerman '87, a political science subject on Libertarianism, Marxism, and Anarchism taught by Mr. Perlman, and an experimental course in 18.06 Linear Algebra which involved computer graphics, developed by ESG tutors Martha Hiller '86 and James Keller '87.

The arrival of a cluster of IBM PC/ATs from Project Athena in June 1985 has focused a good deal of interest at ESG on ways of utilizing computers in undergraduate education. Dr. Janet Murray, a former humanities staff member at ESG, has continued her work on the Athena Language Learning Project and the Athena Writing Project and is using a number of ESG students in key roles in both projects. She will begin testing the products of these projects in the ESG community in the coming year. Efforts to connect computers and academic subjects which began on a small scale this year will be expanded into different fields as staff availability and student interest permits.

The success of the undergraduate seminars offered at ESG this year has stimulated interest in continuing similar seminars in the future. Particular attention will be paid to increasing student participation in new seminars and projects wherever possible. We will also continue our efforts to involve more MIT faculty members in advising and teaching roles at ESG through such opportunities as UROP, undergraduate seminars, and the freshman advising program.

HOLLY B. SWEET
J. KIM VANDIVER
The George Russell Harrison Spectroscopy Laboratory is engaged in fundamental and applied research in modern spectroscopy for the purpose of advancing our knowledge of the structure and dynamics of atoms and molecules and the properties of liquids and solids. Techniques include the use of lasers, microcomputers and other data acquisition systems.

An interdepartmental laboratory, the Spectroscopy Laboratory encourages participation and collaboration among members in the various disciplines of science and engineering. This past year there has been participation from several MIT departments including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Chemical Engineering, and Mechanical Engineering. Outside collaborations with Harvard Medical School and Boston University, Bell Laboratories, and several other nearby academic and industrial organizations have further strengthened the interdisciplinary research activities of the Laboratory.

This past year has been one of continued growth in resources and personnel. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, were appointed Assistant Directors and join the Director, Professor Michael S. Feld, Professor of Physics, in administering the Laboratory. Robert Quinn, Senior Technician, was promoted to the staff.

MIT Laser Research Center

The MIT Laser Research Center, a National Science Foundation Regional Instrumentation facility housed in the Spectroscopy Laboratory, is now in its fifth year of operation. The Center 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 devoted to spectroscopic research. They are made available free of charge to qualified scientists and engineers from MIT and outside organizations.

Current available equipment includes continuous wave (CW) and pulsed dye lasers in the visible and near ultraviolet, CW and pulsed CO$_2$ lasers, a tunable diode laser spectrometer, and a laser Raman spectrometer. All are interfaced with microcomputers which control experiments and collect and analyze data. Auxillary equipment includes a transient digitizer and an optical multichannel analyzer. This past year 51 projects were conducted at the Center in atomic, molecular and solid state physics (15); physical and inorganic chemistry (15); biochemistry and medical science (11); and engineering and applied sciences (10). Eighteen of these have been originated by MIT Core and other faculty, 28 by researchers from other academic institutions, and 5 from industry and government laboratories. Scientists from Brazil, Argentina, China, India, Canada, and Israel have worked at the Center. Results of these projects have been published in 62 papers and conference reports and 6 theses.

RESEARCH HIGHLIGHTS

Professors Robert Field and James L. Kinsey and Dr. George Scherer, all of the Department of Chemistry, are using stimulated emission pumping as a tool to study highly excited vibrations of the acetylene molecule in its electronic ground state. The primary goal of this research is to understand the transition from 'regular' or 'quasiperiodic' behavior at low vibrational energy, to apparently chaotic motion at high vibrational energy. An attempt is also being made to observe isomerization from acetylene to vinylidene on the ground electronic singlet potential energy surface.

Professors Field and Kinsey are collaborating with Professor Richard Redington of Texas Technical University on stimulated emission pumping studies of H-atom tunneling in the molecule tropolone. Due to the complexity of this molecule, this experiment is carried out in a supersonic jet. The purpose is to determine the effect of various types of
vibrations on the barrier to H-atom tunneling. In addition, Dr. Redington and Dr. Scherer have carried out laser-induced fluorescence experiments on acetylene in this jet. The results of these experiments have clarified the nature of perturbations in the lowest singlet excited state of acetylene.

Professor Mark S. Wrighton of the Department of Chemistry is investigating the primary events following photoexcitation of metal complexes having relatively long-lived excited states. An important aim is to characterize excited states and intermediates resulting from excited state reactions. A crucial set of experiments studies the Raman spectra of the excited states of metal complexes such as \([\text{RuL} \text{L'}]^{2+}(L, L' = 2,2'-\text{bipyridine}, 4,4'-\text{dimethyl}-2,2'\text{bipyridine}, \text{and} 4,4'\text{-dibromo}-2,2'\text{bipyridine})\) to establish the electron distribution in excited states that may be useful in bringing about visible light-induced charge separation, which is important in energy conversion. In another study, transient Raman spectroscopy is being used to establish the dynamics of excited state electron transfer involving macromolecular electron acceptors consisting of an array of covalently linked redox subunits arranged according to their redox potentials.

Professor Stephen J. Lippard of the Department of Chemistry is continuing his studies of the Raman spectra of model compounds for polymetallic iron centers in enzymes. Work was initiated on a hydroxide-bridged analogue of the \(\mu\text{-oxo-bis(}\mu\text{-acetato)}\text{diiron(III)}\) complex described previously, and is presently being extended to a \(\mu\text{-oxo-bis(}\mu\text{-phosphodiesters)}\) derivative. The resonance enhanced band in the latter complex are shifted significantly from those in the acetato complexes as a result of changes in the geometry of the \(\text{Fe}_2\text{O}\) core. Studies of polynuclear iron-oxo clusters as models for ferritin are also in progress.

Professor Richard R. Schrock of the Department of Chemistry is studying dimetallic \(\mu\text{-dinitrogen complexes containing tungsten or molybdenum in its highest possible oxidation state. Such unique species are intended to provide information concerning how molecular nitrogen is reduced by the enzyme nitrogenase. Raman studies are crucial to the understanding of bonding in the } M(\mu\text{-N}_2) M \text{ unit.}"

Professor Daniel Kleppner of the Department of Physics continues his investigations of the interaction between an atom and a magnetic field. The diamagnetic shift is comparable to the atomic energy level spacing when the atom's valence electron is far from the nucleus. Recently, lithium atoms were excited to states as high as 50\(p\) in a thermal atomic beam using two photon CW dye laser excitation. These Rydberg states were detected by electric field ionization. Presently, the superconducting magnet to be used in this research is being calibrated by studying the paramagnetism of the lithium principal transition.

Professor Henry I. Smith of the Department of Electrical Engineering and Computer Science is investigating the use of short wavelength (193 nm) excimer lasers to make very fine period, sub-100 nm, gratings for use as diffraction elements in the soft x-ray energy range. Gratings with a period of 100 nm would give about a factor of two improvement in the energy resolution of diagnostic instruments such as time-resolved streak camera spectrometers. These x-ray diagnostic instruments are important tools in laser fusion, laser plasma physics, and x-ray laser research.

The coherent anti-Stokes Raman spectroscopy (CARS) apparatus set up by Professor Steinfeld and his colleagues has been used to monitor the dynamics of excited vibrational levels in chloroethane pumped by a carbon dioxide laser. The scattering amplitude at various Raman-shifted wavelengths can be used to infer populations, which are then compared with predictions of various infrared multiple-photon excitation models.

Professor Steinfeld and his coworkers are also using infrared multiphoton dissociation as a model to study chemical reactions. CARS is used to study the infrared multiphoton excitation and dissociation of ozone, sulfur hexafluoride, and chloroethane. In ozone, the CARS signals are complicated by ozone absorption lines. Ozone absorbs the wavelengths used for the CARS probe, and the upper state of this absorption is coupled to a dissociative continuum. In spite of the very short lifetime of molecules in this continuum, a CARS spectrum of ozone is observed. Upon excitation with an intense infrared source, the ground state signal from both SF\(_6\) and chloroethane are found to decrease. However, no signals corresponding to newly populated states are observed. A
modified Master Equation is used to calculate population distributions for the infrared pumping. A new method, which considers all the vibrational levels of the molecule, is used to calculate the effect of collisional relaxation on the distributions.

Professor Regis M. Pelloux of the Department of Materials Science and Engineering is employing 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 (~10 μm), dictate the use of laser radiation. The objective of this research is to establish criteria for lifetime prediction for critical jet engine components.

Professor Alan J. Grodzinsky of the Department of Electrical Engineering and Computer Science has been developing techniques which use chemical stimuli and electric fields to modulate the transport properties and hydration of polyelectrolyte membranes. The electric field acts as a switch to provide localized control of pH or salt content inside the membrane; the resulting change in intermolecular spacing controls the average pore size of the matrix. With applications in drug delivery and chemical separations, collagen and PMAA membranes show 20-100 fold changes in the flux of fluorescent dyes when membrane charge is changed by 10-20%.

Professor Alexander Rich and Drs. Andrew H.J. Wang and Gary Quigley, all of the Department of Biology, are studying the anthracycline antibiotics daunomycin and the closely related Adriamycin for use in the treatment of human carcinomas. In an attempt to study the manner in which these drugs interact with DNA, daunomycin has been co-crystallized with a self-complementary hexanucleotide pentaphosphate, g(CpGpTpApCpG). The crystal structure of this drug-DNA complex has been solved at 1.5 Å resolution, revealing the stereochemical requirements for DNA binding and the ways in which the DNA changed its shape to accommodate the drug. The fitting of the electron density map was carried out using in the Spectroscopy Laboratory's optical comparator.

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 are currently comparing the structures of several daunomycin derivatives complexed to the original hexanucleotide sequence, as well as to related DNA sequences. By solution of these structures, the specific chemical alterations and their effects on complex formation as well as on the mechanism of action of the drug can be studied.

Professor William H. Orme-Johnson and Dr. Mark A. Walters of the Department of Chemistry have determined the nature of N-methylformamide ligation to the metal sites of the molybdenum-iron cofactor of nitrogenase by the method of Fourier transform infrared spectroscopy. As an ancillary technique, these investigators attempted to obtain the Raman spectrum of the cofactor. This effort was hampered by sample fluorescence.

Professor Feld and Drs. Dasari and John E. Thomas of the Spectroscopy Laboratory continue their research on laser-induced nuclear orientation, which has been successfully applied in a tabletop experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short lived (1 μs) Rb atoms. Values for the nuclear magnetic moment and isomer shift have been obtained. The lifetime of this nucleus is a thousand times shorter than that of any previously studied by optical methods. Present experiments to obtain sub-Doppler narrow gamma resonances are in progress.

Professor Feld and Dr. Thomas are studying new aspects of quantum transport phenomena in atomic and molecular vapors using photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no classical analog. Results include measurements of two level optical radiator collision-induced velocity changes with a few cm/s resolution and magnetic state scattering of isolated multipole moments.

Professor Feld and Drs. Thomas and Dasari have developed a new infrared photon echo spectrometer using acousto-optic intensity modulation of CW CO₂ laser radiation to generate short input pulses. A digitally-enabled RF driver is employed to achieve scattered light limited rejection ratios of 10⁻¹⁰. This system has achieved the first resolution of velocity changes accompanying infrared radiator reorientation.
Professor Feld and Dr. Thomas are investigating transverse effects in the superfluorescence (SF) of a sample of excited rubidium atoms using dye laser excitation. These studies, the most precise ever undertaken, have demonstrated that coherent ringing is an intrinsic property of SF in extended samples, resolving a long standing controversy. New measurements of SF in a resonator are currently in progress to study quantum fluctuations in a single longitudinal and traverse mode of the optical field in a cavity, and the SF quantum initiation process.

Professor Feld and Dr. Carter Kittrell of the Spectroscopy Laboratory, Dr. Barry Sacks of Leonard Morse Hospital, Natick, MA., and Drs. John Kramer, Floyd Loop and Ross Gerrity of the Cleveland Clinic Foundation are developing a system for treating atherosclerosis using laser light delivered percutaneously through optical fibers. The work encompasses the theory of photoablation of tissue, the dosimetry of plaque removal, tissue spectroscopy and development of new type of "smart" laser catheter which incorporates a transparent, protective optical shield. Irradiation of human arterial wall in vitro with argon ion laser light causes the tissue to fluoresce; the emission of atherosclerotic plaque has been found to differ significantly from that of normal artery wall. The results indicate that remote in situ identification of diseased arterial wall via an optical fiber catheter seems feasible, and can be used as a diagnostic just prior to laser treatment of tissue.

MICHAEL S. FELD
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. LNS also supports some projects involving application to other fields of experimental techniques developed through its primary activities. 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. In high energy physics, there are major projects in the U.S. at Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; and the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California. Abroad there are experiments at the German Electron Synchrotron Laboratory (DESY) in Hamburg, Germany and at the European Center for Nuclear Research (CERN) in Geneva, Switzerland. The third field is heavy ion physics with activities at Brookhaven National Laboratory (BNL) and Oak Ridge National Laboratory (ORNL).

Intermediate Energy Nuclear Physics

The principal activity in this field is centered at the Bates Linear Accelerator Center, which functions under the direction of Professor Ernest J. Moniz. This laboratory, located in Middleton, is the national user facility for intermediate energy electro-nuclear physics, with electron and photon beams used for precision studies of nuclear structure and for exploring the reaction processes associated with fundamental understanding of the nuclear force. MIT faculty and Bates staff physicists, and approximately 125 users from about 50 other universities and laboratories in the US, Canada, Japan, and Europe, are presently engaged as initiators or collaborators in active experiments. Twenty-eight MIT graduate students were associated during the past year with the intermediate energy nuclear physics programs.

A vigorous program of electron scattering experiments using the very high precision energy-loss spectrometer continues to yield fresh insights into nuclear structure. This unique spectrometer facility is being utilized to address a variety of fundamental questions, including the shape and collective motions of heavy deformed nuclei, the electromagnetic structure of few-body systems, and the role of mesons in determining the short-range structure of nuclei. Many of these experiments have been made possible by the increase in the maximum beam energy to 750 MeV by beam recirculation. The maximum energy is now being increased to 850 MeV, with a further increase to 1 GeV anticipated in 1986.

A major program of studies characterized by large energy transfer to the nucleus is underway in the second experimental hall. This program, involving the electromagnetic production of pions and/or the emission of energetic nucleons has been made possible by the completion of three large-acceptance magnetic spectrometers and a $\pi^-$ spectrometer. For example, coincidence spectra have revealed a qualitatively new response sensitive to the short-range structure of the nucleus. A universality was found in exciting the nucleon inside the nucleus. The pion production program is now providing a new spectroscopic tool for studying nuclear spin densities.

Initiatives to provide qualitatively new opportunities are underway. A polarized electron source, built in collaboration with Yale University physicists, is under construction at Bates. This will be used first in a unique test of the unified theory of electromagnetic and weak interactions and subsequently in a variety of nuclear studies. A complementary major initiative of measuring nuclear spin observables will test the description of nuclei in terms of the underlying quark structure. Longer range plans for the laboratory, center on construction of a pulse stretcher ring to provide continuous electron beams. Building upon previous developments, this upgrade will provide important new research opportunities through intermediate energy coincidence studies.

Complementary to the Bates experiments are investigations by the MIT group at other accelerator facilities. A program of studies of pion-induced reactions, such as charge-exchange and absorption, continues at the Los Alamos Meson Physics Facility. These experiments, as well as the photo-pion studies at Bates, are important to obtain a good understanding of pion-nucleus interactions. Other investigations at Los Alamos, at the Indiana University Cyclotron Facility, and at Bates have been crucial for making efficient use of the complementary nature of nuclear probes.

Another group in intermediate energy nuclear physics is collaborating with physicists at Brookhaven National Laboratory in a study of hypernuclei using separated K meson beam in order to investigate the binding of $\Lambda$ and $\Sigma$ particles in nuclear matter. Data have been obtained which have allowed detailed comparisons with nuclear model calculations. This group is also exploring jointly with physicists at Bell Laboratories the feasibility of constructing a detector which would measure both the flux and spectrum of low energy solar neutrinos.
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 newly approved 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, 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, 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 scheduled for the end of 1988. 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. The group plans to continue to take data at the highest energy of 46.78 GeV to search for 1) new types of particles, quarks, leptons, Higgs etc.; 2) measure the $\mu + \mu -$ charge asymmetry and study Z propagator effects; 3) search for new leptons, supersymmetric scalar particles; 4) study QCD jets.

The Accelerator Physics Collaboration (APC) Group is conducting experimental research on the nature and interactions of photons, hadrons, and neutrinos. The experiments are performed at two of the country's national accelerator laboratories: the Stanford Linear Accelerator in California and the Fermi National Accelerator Laboratory (FNAL) in Illinois.

In the Stanford experiment, the goal is to see how photons, which are massless vector quanta of the electromagnetic force, change into vector mesons, which are massive quanta of the nuclear force. Since one of the vector mesons which the photon can change into is the D meson containing a charmed quark, these charmed mesons are being studied intensively. Most of the work involved in this study is now complete. Several papers have been published and work is continuing on the final papers.

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 into the question of hadron-nucleus collisions. This topic is of great interest, not only for high energy physics, but also for heavy ion physics.

We are currently taking data at FNAL in the world's highest energy neutrino beam. This experiment is using a holographic bubble chamber which was designed for our tau neutrino experiment described below. In this experiment we will be looking at a new domain in neutrino physics where new phenomena might be found. The holographic bubble chamber meets the specifications described below.

A future experiment has been approved for running at FNAL in 1989, apparatus for which is being designed and built now. The goal of the experiment is to search for a hitherto undiscovered particle, the tau neutrino. Proof or denial of its existence will have major theoretical consequences. This experiment will use a new technique being developed explicitly for it, the holographic photography of a bubble chamber. 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 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 electro-weak 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.
Another group, in collaboration with Professor Alexander Rich of the Biology Department, has developed a device for measurement of bone loss associated with osteoporosis. If proposed work is continuing on a device for medical imaging. In conjunction with this same group at BWH we have also developed a gas scintillation camera for cardiac imaging which is presently under test at MIT. The present unit has a factor of three better energy resolution compared to present instruments and improved data rate capability. This should result in increased reliability in cardiac diagnostic procedures using currently used isotopes such as thallium-201 (where good energy resolution is required) and for first pass studies using newly developed short-lived isotopes such as tantalum-178 (where high data rates are required). We are working on a high speed signal processing technique to sustain high rates required in such applications.

Applications of Nuclear Techniques
The Medical Imaging Group has continued its collaboration with similar groups from Brigham and Women's Hospital (BWH), Harvard Medical School (HMS), and Massachusetts General Hospital (MGH) in the development of new clinical instruments. A prototype positron emission tomography (PET) system is under test at BWH and a larger unit for cardiac imaging is under construction at MIT. As part of this project we have also developed new reconstruction algorithms for three dimensional imaging which may have application outside of medical imaging. In conjunction with this same group at BWH we have also developed a gas scintillation camera for cardiac imaging which is presently under test at MIT. The present unit has a factor of three better energy resolution compared to present instruments and improved data rate capability. This should result in increased reliability in cardiac diagnostic procedures using currently used isotopes such as thallium-201 (where good energy resolution is required) and for first pass studies using newly developed short-lived isotopes such as tantalum-178 (where high data rates are required). We are working on a high speed signal processing technique to sustain high rates required in such applications.

Work is continuing on a device for measurement of bone loss associated with osteoporosis. If proposed funding becomes available we hope to expand this work.

Another group, in collaboration with Professor Alexander Rich of the Biology Department, has developed an X-ray diffraction facility for protein crystallography based on a wire drift chamber detector originally developed at CERN. The instrument is now in regular use by members of the Biology and Chemistry Departments and by scholars from other institutions.

Also, LNS, through its high energy program, is partially supporting the efforts of a group who are developing cryogenic techniques of producing polarized protons for use in targets, jets and sources. In collaboration with a group at Brookhaven, a design is being undertaken of a cold jet of nuclear polarized atomic hydrogen for use in the AGS. At MIT the production of solid nuclear polarized molecular hydrogen is being studied.

Particle Theory
The "standard theories" of the interaction of quarks and leptons through gauge fields, quantum chromodynamics (QCD) for the strong interactions, the Weinberg-Salam-Glashow theory for the electromagnetic and weak interactions and general relativity for gravitational interactions 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? The most elegant and simple "grand unification" of strong, electromagnetic and weak seems to fail the experimental test by predicting an unobserved rate of proton decay, but more complex schemes exist, and form the basis of scenarios of the development of the very early universe. We are a leading group in the study of these "inflationary universes" which has now reached the stage of detailed confrontation with the known facts about later development of the cosmos. The apparent paradoxes which would arise in the dynamics of a bubble of metastable vacuum surrounded by true vacuum have been resolved in a simple and beautiful picture.

In another investigation on the frontier of particle physics and astrophysics we have studied whether "strange matter" with a different quark composition from ordinary nuclear matter could be stable and could have survived from its formation in the early universe. The most likely "strange" objects seem to be star-size. Data from a laboratory search proposed by us in which meteoritic matter was bombarded with gold ions is being analyzed.
Last year the first hints appeared in experimental results from CERN of clues to what may lie beyond the "standard" theory. We have put much effort into analyzing the evidence and trying for possible theoretical explanations. In particular an alternative to the standard theory with a more subtle dynamics is being explored in depth. Even within the standard theory a whole range of fundamental dynamical questions remain to be resolved and this continues to be an active area of research with many diverse approaches ranging from traditional field theory to the construction of special purpose array processors for numerical simulations of QCD. This merges with the interest of the nuclear theory group in the role of quark-gluon degrees of freedom in nuclear collisions.

The study of the structures implicit in quantum field theory continues to reveal rich possibilities. We have pursued a new way of understanding many of these structures in terms of mathematical "co-cycles" and developed and applied them in contexts ranging from the Hall effect to gravitational theory. We are actively working on supersymmetric field theory on curved space, a subject which ties in with some of the most exciting speculation on unification.

Nuclear Theory

An area of fundamental interest is the role of underlying quark and gluon degrees of freedom in the nucleon, in nucleon-nucleon interactions, and in nuclear structure. Although it is believed that the structure and interactions of hadrons are governed by quantum chromodynamics (QCD), there is as yet no quantitative theory of even the most basic questions. How do we understand the properties of a nucleon in free space, how is a nucleon altered when it is embedded inside a nucleus, and why is low energy nuclear physics so little affected by the internal structures of nucleons? These questions are being approached both from the perspective of lattice gauge theory, and in the context of non-relativistic quark models. Studies of nuclear matter have focused on the clustering of quarks into nucleons and the experimental signature of non-nucleonic degrees of freedom. Hadron-hadron interactions have been studied in both the non-relativistic quark model and in the MIT bag model. A major new initiative has been undertaken in investigating the collisions of relativistic heavy ions, including study of the properties, evolution, and hadronization of the quark gluon plasma, understanding particle multiplicities, and seeking experimental signatures of new physical phenomena.

Nuclear many-body theory provides the foundation for many facets of nuclear theory and has therefore been an area of continuing interest. The success of relativistic models of nucleon-nucleus scattering has motivated continued efforts in the study of relativistic many-body theory. Recent developments in functional integral and stochastic methods have proven fruitful in a variety of applications, ranging from problems in traditional nuclear structure of the study of relativistic nuclear models and field theory. Progress has continued in the theory of nuclear collective motion, utilizing both time-dependent perturbation theory and the Born-Oppenheimer approximation.

Electromagnetic interactions have been a long-standing focus of theoretical interest in the group, both by virtue of the unique precision of the probe and the commitment to the experimental program in electron scattering. A detailed study has been made of the additional nuclear structure which is revealed by studies with polarized electron beams, polarized targets and by coincidence experiments. The structure of the electromagnetic current operator in nuclei is being studied, both from the perspective of meson exchange currents and quark substructure.

Summary of Support

Participants in the various research programs during the past year amounted to approximately 450 people. This includes 54 academic staff members, 108 graduate students, and at least 36 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 101 research staff members with Ph.D.'s, including visitors and guests, and 149 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least eighteen Ph.D.'s, two M.S.'s, and four B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1985 from the contract with the US Department of Energy (DOE) is expected to total $21,140,000. This represents an increase of about 11 percent over the preceding year. This sum breaks down as follows: operations costs (salaries, wages, materials, services, travel, and overhead) were $14,865,000; of this $5,070,000 was for experimental and theoretical high energy physics, $8,175,000 was for intermediate nuclear energy physics for the support of the Bates Linac facility and research program both at Bates and elsewhere, and $1,620,000 was for nuclear structure theory, hypernuclei, and heavy ion experiments. Equipment costs are expected to total $5,885,000; of this, $4,930,000 will be for high energy physics and $955,000 for medium energy and heavy ion physics. A total of $390,000 will be expended for accelerator improvement, 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 $210,000.

ARTHUR K. KERMAN
The McGraw-Hill Observatory, located on Kitt Peak near Tucson, Arizona, is run jointly by MIT, the University of Michigan, and Dartmouth College. A major expansion of the astronomical facilities of the observatory is now nearly complete. The new 2.4m telescope and its associated building are in place. The final precision polishing of the 2.4m diameter primary mirror will be completed this summer, allowing installation and final check out of the new telescope in the fall. Tests of the mirror show that its image quality will exceed specifications. A new computer facility based on two SUN workstations was delivered this year and is being integrated. These computers will service both the 2.4m and the existing 1.3m telescope, and will provide a very considerable improvement in instrument control and on-line data reduction capabilities. Improvements in auxiliary equipment include construction and installation of a new image intensified guider/acquisition camera on the 1.3m (a similar unit is ready for use at the 2.4m) and improvements to the MIT CCD camera/spectrograph (called the MASCOT).

As in the past years, MIT observers made 3-4 dozen trips to the McGraw-Hill Observatory to perform a wide variety of astronomical observations using the 1.3m telescope. Approximately half these trips were made by students, including undergraduates. Professor Claude R. Canizares and graduate student John Kruper have continued their studies of active galaxies and quasars that have also been observed in the X-ray band. They are concentrating on understanding the nature of a class of "red" quasars found in X-ray surveys. Professor Canizares and Dr. Gerard Kriss (U. Michigan) incorporated earlier such studies in a statistical analysis of the X-ray and optical properties of quasars. Professor Canizares and graduate student Peter Vedder have measured hydrogen H alpha emission from the central parts of clusters of galaxies. This emission comes from filaments of gas that condense out of a cooling, accretion flow that continually feeds the central galaxy from the reservoir of hot gas permeating the cluster. Dr. Jeffrey E. McClintock and Dr. Ronald A. Remillard carried out photometric observations of the X-ray nova A0620-00 at the 1.3m telescope with simultaneous spectroscopic observations at the 4m telescope of the Kitt Peak National Observatory. Professor Hale V. D. Bradt and Dr. Remillard continued their program of identification of the optical counterparts to X-ray sources discovered with the HEAO-1 satellite. Professor George W. Clark performed surface photometry of the peculiar galaxy ARP 227 and of other galaxies to obtain quantitative measures of the brightness and color of the multiple shells that appear in these systems. The exact origin of these shells is not certain, although they are believed to be strings of stars, whose structure reveals dynamical information about the host galaxy and its possible merger with other smaller galaxies. Dr. George Ricker and Professor S. G. Kleinman (U. Massachusetts) are collaborating in a search for "super star clusters" in both dust-rich nearby galaxies and in strong infrared galaxies discovered with the IRAS satellite. Dr. Ricker and graduate student Roland Vanderspeck are continuing their astrometric search for high proper motion optical counterparts to gamma ray burst sources.

Professor Bernard Burke and graduate student Jacqueline Hewitt continued their program of optical identification of sources discovered in a comprehensive radio survey. James Jackson observed H alpha emission from nine starburst galaxies to make a comparison with radio continuum and molecular line observations. Starburst galaxies show evidence for a large population of bright, young stars, indicating the sudden triggering of widespread star formation in the recent past.

Professor David Jewitt and Dr. Ricker have used the MASCOT on the 1.3m telescope in a novel program of 1 micron spectrophotometry of planetary nebulae. Several unidentified spectral lines have been found, together with strong helium emission and possible evidence for a new optically variable planetary nebula. Professor Jewitt, Dr. Ricker and graduate student Karen Meech continued their observations of comets. Highlights include the first detection of mass loss from Comet Halley and the determination of the rotation of a cometary nucleus.
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 reflecting telescopes, and a small building that houses a workshop, darkroom, computer, and observers' quarters.

Improvements to the Observatory facilities this year included the acquisition of a Celestron 14-inch telescope, equipped with a photoelectric photometer, that was installed on one of the four piers in our new sliding roof building. We also obtained for the new building a 5 1/2-inch astrograph, which was kindly loaned to us by Michael Mattei. Bradley Waller (Class of 1986) is aligning this astrograph in preparation for his senior thesis on the recovery of lost asteroids. Our data acquisition capability was upgraded with the addition of two portable computers. The software for these machines was written by Michael Ressler (Class of 1986).

The introductory seminar in observational astronomy (12S23), taught fall and spring terms by Dr. Linda French, continues to make extensive use of the Observatory for visual and photographic observations. Dr. French also taught the advanced laboratory course (8.287-12.117J Observational Techniques of Optical Astronomy), in which 18 students carried out independent projects at the Observatory. Notable among these was a period and phase determination for the dwarf Cepheid CY Aquarii by Scott Ritterbush (Class of 1988), who reported his results at the fall meeting of the American Association of Variable Star Observers.

New features in dwarf Cepheid light curves were observed by Mr. Ressler and Alberto Sadun. Corbin Covault (Class of 1985) used the 16-inch telescope to test the infrared photometer that he constructed for his senior thesis, submitted to the Department of Physics. Student research projects sponsored by the Observatory in conjunction with the UROP Program included (i) the construction of a set of precision clocks by Mr. Ressler, under the supervision of Richard Baron, which were used to time stellar occultations by the Uranian rings and (ii) photometry of occultation candidate stars by Guarionex Morales (Class of 1986) and Steve Gaiser (Class of 1986).
Statistics Center

The Statistics Center (SC) was established in 1981 to provide educational and research opportunities for students and faculty interested in statistics. The academic staff of the SC is drawn mainly from Mathematics, the Sloan School of Management, and Economics. The SC is under the direction of Professor Roy E. Welsch. Next year Professor M. Anthony Wong will join the Center as Associate Director. Approximately 15 graduate students were enrolled in master's and doctoral degree programs. There are 12 faculty affiliated with the Center, one principal research scientist, and three research scientists.

Statistical Research at the SC covers a broad range of topics including estimation, classification, time-series analysis, clustering, and stochastic processes. Applications of these topics included the study of nuclear reactor safeguards, earthquake aftershocks, human gait data, marketing models for detecting consumer attitude changes, and credit card thefts.

The Concurrent Computing Group under the direction of Virginia Klema is building hardware and software environments to support research on numerical algorithms and scientific applications in a concurrent computing environment. These systems are being used for high resolution spectrum estimation, signal processing, and computationally intensive statistical methods such as the bootstrap.

The Computational Statistics Laboratory, under the direction of Roy E. Welsch and Stephen C. Peters, is developing hardware and software systems for research on statistical strategy, statistical graphics, and expert systems for data analysis. Equipment has been provided by Xerox and IBM and more is being purchased with a DOD instrumentation grant.

This year research at the SC has been supported by the National Science Foundation, US Army Research Office, Office of Naval Research, NASA, and the Air Force Office of Sponsored Research.

RESEARCH ACTIVITIES

Markov Decision Models

The problem of the early detection of possible diversions of nuclear material is analyzed as a Markov decision problem. This approach is contrasted with several competing approaches. Special computer programs have been developed to solve the Markov decision problem and to compare the efficacies of various strategies to detect diversion. In addition some attention is given to the relationships among various approaches and their theoretical bases.

In this research one important characteristic of the real situation has been neglected. That consists of the dependence of successive estimates of the materials balance, i.e., the amount diverted. While an extension of our approach to that problem is outlined, it is not treated in detail.

Regression Coefficient Estimation

A source of difficulty in estimating the effect of one variable on another, especially in observational studies, is that the explanatory model may omit another variable which affects the dependent variable. Under circumstances where we do not have controlled experiments and where the omitted variable is correlated with the explanatory variables included in the model, ordinary regression analysis will give biased results which can be misleading. There are examples, in analytical chemistry for example, where it is known that the omitted variable and its effect are positive and that it is sometimes negligible. In such cases, it is possible to exploit that fact to estimate the desired effects.

Bounded-Influence Estimation and Diagnostics

In 1982 Bill Krasker and Roy Welsch proposed a new type of bounded-influence regression which bounds the influence of small subsets of data on coefficient estimates relative to the standard deviation of these estimates at the central (uncontaminated) model. This procedure has proved to be effective for estimation, prediction, and diagnostics. However, for inference there is one major drawback. The covariance matrix that results does not have a bounded-influence function.
If the K-W approach is modified to bound influence on coefficients relative to the standard deviation at the contaminated model rather than the central model, then the covariance matrix for the resulting estimators does have a bounded-influence function. We are exploring the properties of this new approach both analytically and with examples. These ideas should allow the computation of bounded-influence (or stable) confidence and forecast intervals. Such intervals are not overly sensitive to small fractions of aberrant data. Conversely, it is possible to discover what small subsets are potentially influential on forecast and confidence intervals.

Clustering

Estimating and making decisions on the number of population clusters are two unaddressed statistical problems in clustering. Recent efforts directed at these problems has led to the development of clustering diagnostics, which were shown to be useful in discriminating populations with different numbers of modal clusters in a simulation study.

Also under development are "block clustering" algorithms which would cluster the objects by partitioning the data matrix into a number of blocks—submatrices of the data matrix within which the data values are similar. Algorithms designed to optimize existing clustering criteria like k-means and k-median cannot be used for block clustering, because the clusters they produce do not necessarily correspond to partitions of any one (or more) of the data variables. A new class of clustering criteria has been identified whose corresponding optimal partitions may give clusters of objects lying in hyper-rectangles in the space spanned by the data variables. Partitioning algorithms based on these criteria are being developed and tested.

Classification

The problem of classifying a credit card purchase involves the use of a "loss structure" which is a function of some of the classifying variables. Standard classification procedures cannot handle this case. A graphical tool has been developed for displaying "statistical events" data so that the usage patterns of counterfeit cards can be readily recognized. A non-parametric pattern classifier has been found to be a cost-effective tool for detecting fraudulent purchases.

Nonstationary Point Processes

Many aftershocks followed (and are still following) the large earthquake which occurred in February, 1975 near the north China town of Haicheng. This research concerns an analysis of 1222 of the aftershocks which had taken place by the end of 1978. The analysis consists of two parts, a "first order" analysis and a "second order" analysis. In the first part an intensity function, based on two seismological models, "Omori's law" and the "magnitude-frequency" law, is fitted to the time-magnitude data. A method intended to be robust against clustering in the data is used as well as a maximum likelihood approach. In the second order analysis a "stationary" aspect of the second order dependence structure is sought. Four models have been tried. One of these models seems to work but only when a "robust" estimation procedure is introduced.

Identification of Transfer Functions

Identification and estimation of transfer function (distributed lag) models, is an important research area, particularly aspects related to the determination of model orders using information criteria. When the true process actually has a rational spectrum the theory is largely complete. What remains is the more realistic problem of determining the behavior of order estimation procedures when only a rational approximation to the true spectrum is available.

Recursive Estimation of Linear Systems

This research involves the estimation of parameters for a scalar linear system with rational transfer function so that the estimates are updated each time a new data point comes to hand. Two well-known algorithms have been compared by simulation with a method related to the three-stage algorithm of Hannan and Rissanen (1982); a computation scheme using Givens transformations has been developed which makes the three-stage recursive algorithm economical. A central limit theorem for the estimators obtained by the three-stage process has also been proved.
Limit Theorems for Likelihoods

Kendall (1965) proposed a data analytic technique for analyzing non-degenerate ANOVA tables. The technique consists of minimizing a normalized sum of squared deviations over all possible monotone transformations of the data. He provided no theoretical justification for the procedure, but did produce some examples. It can be shown that the procedure is consistent, and work is underway on its asymptotic distribution (since it estimates an optimal transformation over a rather large class this is a non-trivial problem). It is still necessary to characterize what happens in the degenerate case (which is usually useful as a null hypothesis for significance testing).

M-Estimators for Symmetrized Regressions

It is known that M-estimators fail in the regression case when the underlying distribution is skewed. This is rather surprising since, except for the location parameter, the regression equation has about it an inherent symmetry. A computationally simple technique has been developed which enables one to successfully treat skewed regression data as though it were symmetric.

Concurrent Computing Group

The concurrent computing group consists of George Cybenko, Elizabeth Ducot, Virginia Klema, Richard Kefs, and Joseph Sebeny.

During the past year work has concentrated on building a hardware and software environment to support research on numerical algorithms and scientific applications in a concurrent computing environment. This environment consists of a number of microprocessors, all Intel components, linked together. The VAX 11/730 is a communications device and a file server for the concurrent environment. All of the Intel microprocessors have the IEEE standard for binary floating point arithmetic in hardware.

Research progress includes a software parallel tasker that permits a user to locate code and data on multiple processors, monitor communication and execution of the application, and report results to the user. Ongoing research includes the design and implementation of numerical algorithms, particularly the components of linear algebra, that are needed for applications in signal processing. Additional research is also underway on minimal operating systems for concurrent computing systems.

Many questions arise in research on concurrent computing with respect to the level of granularity of the processing elements. Our processing elements are medium granularity but can be viewed as an interface or intermediate host to very small granularity components, say, systolic arrays.

A number of algorithms for performing standard matrix computations and suitable for loosely-coupled multiprocessors have been identified. Those methods will soon be implemented and evaluated on our multiprocessor architecture.

A consequence of this work has been the identification of a relatively small number of control-synchronization structures that can perform a variety of basic matrix computations. These control-synchronization structures are very high level, global constructs quite different from the language extensions that researchers have been studying for parallel computing.

A concurrent simulator and graphics display postprocessor have been designed and implemented.

Signal Processing

New computational techniques using Pisarenko’s method were discovered and studied. This work together with previous algorithmic work for the Toeplitz eigenvalue problem constitutes an extremely efficient and simple computational implementation of Pisarenko’s method. The whole procedure for sinusoidal frequency extraction uses only repeated applications of the Levinson-Durbin algorithm on sample correlation matrices and a single call to a tridiagonal eigenvalue solver. All the required computations have been studied already from the point of view of parallel implementation.

State of the art methods for direction finding and beamforming are extremely difficult to implement in realtime because of their computational complexity. Initial studies into the concurrent implementation of these methods has been encouraging. In particular, a simple balanced parallel method for singular value updates by rank one modifications has been identified and optimal steering vector calculations can be readily distributed. Computational experiments will follow shortly.
The first complete stability analysis of the correlation lattice methods has been performed. The algorithm is comparable to the modified Gram-Schmidt method for solving linear least squares problems. Some computational experiments have lead to some interesting conjectures about condition numbers of Toeplitz matrices and the relationships between successive filter coefficients.

Computational Statistics Laboratory

This was the first year of operation for this Laboratory. The first project involved expert systems and computing environments for the study of statistical strategy and began in January with the donation of three Xerox workstations with Interlisp and LOOPS. A demonstration system is now ready. The goal is to provide systems which guide users of data analysis techniques by presenting options (trees and menus) on a high resolution graphics/Lisp workstation. In phase one these options reflect expert judgment (coded in Lisp) based on particular statistical situations and information from the user. In phase two the data will also help direct the analysis in consultation with the user and machine expert.

IBM has loaned us three 3279 color workstations and a 3277/Tektronix high resolution storage tube display to study graphical data analysis using the GRAFSTAT system (also from IBM).

In the near future the Laboratory will be equipped with a Sun 170 file server, two Sun 50 monochrome graphics workstations and a Sun 160 color graphics workstation. These systems will be used to explore the use of advanced graphical techniques in statistical research including motion and color.

Educational Programs

The Statistics Center supervises interdepartmental graduate degree programs in Statistics. During 1984-85, fifteen students were enrolled in these programs and two Ph.D. and two MS degrees were awarded. An important part of the SC educational program is a special 13 week topics course consisting of lecturers (usually of one or two weeks duration) by distinguished visitors who are compensated for their time. The speakers this year were: T. Cacoullos, R. Carroll, W. Eddy, H. Robbins, J. Rustagi, J. Sethuraman and J. Yahav.

The weekly Statistics Center seminar series provides additional opportunities for reports on both applied and theoretical research. Speakers this year included Don Andrews, Victor Solo, Don Rubin, L. J. Wei, and John Pratt.

ROY E. WELSCH
Enrollment of regular graduate students continued the pattern of growth which has been experienced in all but a few years since World War II. As shown in Table I, the total regular graduate student enrollment increased by 126 students or 2.7% over the preceding year, an increase that is consistent with the approximately three percent per year growth which has been observed for more than a decade. Last year's report took note of the fact that we have entered a period in which graduate enrollment exceeds undergraduate enrollment; based on data for the fall term 1984 the ratio of graduate to undergraduate enrollment grew to almost 1.06 (G = 4757, U = 4505, G/U = 1.056). In the presence of rigid constraints on undergraduate enrollment, the absence of constraints on graduate enrollment, and the continued growth of support for graduate research assistants that ratio is likely to continue to grow.

The growth in graduate enrollment was experienced in all five of our schools. In four of the schools the growth was remarkably consistent at about three percent. In the School of Science, which last year reported a second year of decreased enrollment, the growth rate was only about one half of that value (i.e., 1.5%).

It is particularly interesting to note that a major portion of the growth in graduate enrollment can be attributed to growth in the number of women in our graduate population. Table I shows that more than half (53%) of the 126-student increase is accounted for by the increase of 67 women graduate students. This behavior is consistent with national trends in science and engineering where, for example, a decline in the number of men receiving Doctorates has been more than offset by increases in women receiving Doctorates. Associate Dean Jeanne Richard discusses these and related issues in a subsequent section of this report.

While encouraged by these figures for women graduate students, the picture for underrepresented minority students is disappointing. The minority graduate student population has been nearly constant or slightly declining in recent years at a time when the total graduate population has increased. Consequently, in percentage terms the already small minority population has declined. For example, in the fall of 1979 our 150 minority graduate students represented 3.6% of the graduate population; in the fall of 1984 (see Table I) the ratio had fallen to 3.0% (141/4757). Associate Dean and Assistant Provost John B. Turner discusses these figures and our efforts on behalf of minorities in a later section of this report.

Despite our growing graduate student population, the number of graduate degrees awarded declined slightly (see Table II). The number of Doctorates awarded increased by 32, but this was more than offset by a decline of 49 Master's and Engineer's degrees. Although the data vary considerably from year to year, there is a hint here of a trend towards a greater percentage of doctoral students in our graduate population.

Tables IV, V, and VI provide interesting information on the sources of financial support for our graduate students. Table IV attempts to provide a picture of the support situation based on a head count of graduate students for whom we can identify the source of their support and who are receiving at least the equivalent of fall tuition support. Those receiving the lesser amounts of support and/or those receiving support from sources we cannot directly identify are not included in Table IV. The data in Table V are based on dollars of support rather than head count and thus include all sources of support we can identify regardless of size.

By either measure the data in Tables IV and V suggest that we can account for about two thirds (66% in both cases) of the support required by our graduate students. The remainder is accounted for by a combination of awards that are not administered through MIT (Tables IV and V), awards that are less than full tuition (Table IV), funding requirements less than those assumed (Table V), and funding obtained from personal sources and/or loans. The data in Tables IV and V also demonstrate the great dependence of our graduate student support system on research assistantships which account for over half of the students supported as defined by the measure used in Table IV (i.e., 1571/3044 = 51.6%) or in Table V ($13,993,675/$26,630,076 = 52.5%). In terms of total need, as defined in Table V, the research assistantship provides over one third of graduate student support.
Data in Table VI show how the major components of support have varied over time. Of particular note are the data on Fellowships, Traineeships, and Scholarships which declined precipitously in total dollar and percentage terms during the 1970's and have only recently increased to a dollar level equal to that which existed in 1970. Of course, when the effects of inflation are considered the increase of recent years fails to bring us even close to the 1970 situation. In 1970 (see Table VI), the Fellowship, Traineeship, and Scholarship support was equivalent to 65% of our gross graduate tuition revenue; today that source represents less than 14%.

During the past year a change was made in rules governing use of the College Work Study Program (CWSP) allocation for graduate student support. Starting two years ago, salaries supported under this allocation became subject to employee benefit charges, thus reducing the effective size of the CWSP allocation. That reduction was offset during the first year by a special allocation from Institute funds; initially during the past year no provision was made to offset this factor in a similar manner. However, during the year the Provost allowed a permanent change in the administrative rules governing use of the CWSP allocation, such that departments can at their option charge a portion of the tuition of CWSP-supported students to their departmental EB pool. The portion chargeable in this manner has been designed to offset the effects of the employee benefits charges, and thus leaves the effective size of the CWSP allocation at its level of two years ago. Unfortunately, the actual size of the allocation has not increased in recent years.

The Office of the Dean of the Graduate School and the Undergraduate Academic Support Office sponsored a Workshop for Graduate Teaching Assistants in September. The Workshop was designed to acquaint teaching assistants with a sense of the importance of their role and to offer practical ideas for improving their teaching performance. The program included lectures, panel discussion, and small group workshops. Over 180 teaching assistants attended and their enthusiastic response to the program has led us to plan on conducting the Workshop as an annual event. We were particularly gratified by the large number of faculty and staff members who gave up a Saturday in order to participate. A shortened form of the Workshop was also conducted during Independent Activities Period with similar success.

The Dean of the Graduate School took special interest in several activities of the Graduate Student Council (GSC) which had a particularly active year. The GSC drafted a statement of Rights and Responsibilities for graduate students and worked with the Dean to plan a strategy for revision and eventual approval by the faculty of that statement during the coming year. The GSC also began regular publication of a Newsletter which the Dean has found to be an ideal medium for communicating with the general graduate student population. The Dean and GSC also spent some time in discussions concerning the ever-present problems of graduate student housing and the dream of a graduate center.

The Committee on Graduate School Policy (CGSP) carried out its usual academic review functions at the end of each term by reviewing grades, issuing academic warnings where appropriate, and terminating the registration of several students whose performance was unsatisfactory. Positive note was taken at these meetings of the increased use of the relatively new grade of "N", which is used to indicate to students, when appropriate, that progress on their thesis has not been satisfactory. The CGSP also reviewed and recommended candidates for advanced degrees.

The CGSP voted to terminate an existing S.M. program in Textile Technology, and noted also termination by the Department of Electrical Engineering and Computer Science of its S.M. in Industry program. The latter had been established a few years ago in response to initiatives of the Massachusetts High Technology Council, but had failed to attract a sufficient number of students to make it viable. The CGSP also approved arrangements under which students in the new Real Estate Development Program can work simultaneously for a Master's degree in Architecture or City Planning. Such combinations appear to be of particular interest to students currently in the Real Estate Program and since all three programs require more than the minimal number of units, special provisions for dual degrees in these areas were considered necessary. The CGSP also considered requests for two new degree programs - S.M. in Urban Studies and Planning, and Naval Engineer - but deferred action on both programs until the fall of 1985.

The CGSP approved a recommendation from the Chairman of the Faculty to eliminate a listing of approved "Fields of Study" from the MIT Bulletin. This listing has led to some confusion in recent years and was found to contain many entries which are seldom if ever used. While voting to eliminate the listing from the Bulletin, the CGSP noted the need for a properly updated listing and a place such as the Graduate School manual for its publication. A review of the Fields of Study issue, its purposes and its ultimate disposition, is on the CGSP agenda for the coming year.

During the past year the Graduate School engaged in discussions with the Hertz Foundation over the issue of supplemental support for Hertz Fellows. Foundation support for the Fellows provides an excellent stipend plus a tuition allowance which fails to meet MIT's full tuition. Some departments at MIT provide partial research assistant support sufficient to make up the entire tuition shortfall. Other departments allow for supplemental support only to the point that the total package (tuition plus stipend) is equal to that of all other graduate assistants in the department; that latter policy usually
results in somewhat less than full tuition coverage. The Foundation requested that we consider a policy in which MIT would guarantee to make up the entire tuition shortfall in all cases. We have declined to adopt such a policy and instead negotiated a statement of our policy which now appears to be acceptable to the Foundation and which they have incorporated into their literature.

A key staff member of the Graduate School Office, Ms. Leslie A. McIntyre, resigned in October to spend time at home with her family. Her responsibilities were divided among others in the office with Ms. Linda Peterson taking on increased responsibility for the administration of fellows, traineeships, and scholarships, and Ms. Jackie Sciacca taking responsibility for the administration of research and teaching assistantships.

I and my colleagues in the Graduate School Office wish to express our thanks and appreciation to members of the CGSP for their service during this past year. Those terminating their service this year and their replacements are:

Psychology
- Professor Mary C. Potter to Professor Merrill F. Garrett
Chemical Engineering
- Professor Robert C. Reid to Professor William M. Deen
Urban Studies and Planning
- Professor Karen R. Polenske to Professor J. Mark Schuster

FRANK E. PERKINS
MIT's enrollment of graduate degree candidates rose from 4,631 in the Fall of 1983 to 4,757 in the Fall of 1984. This was a 3% increase compared to total graduate student enrollment nationally which remained the same. On the other hand, according to the annual Council of Graduate Schools/Graduate Record Examinations Board (CGS/GREB) "Survey of Graduate Enrollment" a breakdown by disciplines does show an increase of 2.6% in Engineering enrollments. Therefore, it would seem that MIT is less vulnerable to the predicted decreases in graduate enrollment since the majority of our students are enrolled in science and engineering disciplines.

The Fall of 1984 also saw an increase in the number of women graduate degree candidates at MIT. Their number increased from 914 to 981 (7%) and reflects an all time high in percentage of the total graduate population of 21% (Table VII).

The total number of women enrolled reflects their proportions of new and continuing female students exactly with 20.5% new and 21% continuing students (Table VIII). At the same time, there was a slight decrease in the number of both new and continuing male graduate students. In summary, it is exciting to note that the general increase in the graduate student population at MIT was due to an increase in women students.

It is not surprising, therefore, the number of women applicants increased 3% from 1983 while the number of male applicants decreased 5%. As indicated in Table IX the School of Architecture and Planning accounts for the largest increase in women applicants (+18%) and the largest decrease in male applicants (-24%). It is especially heartening to note that more women applied to the School of Engineering (+9%) but puzzling that the number of male applicants dropped (-7%). On a more disappointing note the number of women applicants to the Sloan School of Management decreased (-12%) for the first time in several years and this is also reflected in the numbers enrolled which dropped from 27% in 1983 to 24% in 1984 (primarily in the Master's program).

The number of science and engineering degrees awarded to women as reported in the annual National Science Foundation/National Research Council survey has been increasing steadily, and almost doubled in the last 10 years. In contrast, the number awarded to men has decreased. In Table X we see that although women represented 21% of the graduate enrollment at MIT in 1983-84 they received only 18% of the graduate degrees. It is even more interesting to compare these numbers by School as listed in this table. Tables XI and XII give further details of trends in numbers of degrees awarded to women over the past 10 years. The total number of master's degrees awarded to women in 1984-85 (196) is more than double the number in 1975-76 (93) while the women doctor's degree recipients increased 136% (33 to 78). A dramatic five-fold increase in the number doctorates awarded to women in engineering departments is an encouraging trend although the numbers are small (3 to 15).

In summarizing the number of degrees awarded to women, Table XII shows no increase in percentage of total degrees awarded from 1983 to 1984 (18%). However, there was an increase from 15% to 17.5% in doctoral degrees awarded and a slight decrease from 19% to 18.5% in master's degrees. This indicates that at MIT as well as nationally the gender gap in the number of women receiving graduate degrees is slowly narrowing, especially at the doctoral level. However, nationally, the male doctoral recipients still outnumber females by a ratio of 21 to 1. This trend is also reflected at MIT but with only a 5 to 1 ratio in 1984-85 which was 10 to 1 ten years ago.

A constant and growing concern during recent years has been with financial support for graduate students. Tuition (as well as the cost of living) continues to rise. Women as well as men graduate students are affected. However, it is encouraging to note that more women are competing successfully in national fellowship competitions such as Hertz, NSF, and ONR. In 1984-85 18% (6/34) of the Hertz Fellows at MIT were women. It is anticipated that this will increase to 27% (7/26) in 1985-86. On the national level one-third of the new NSF Fellowships were awarded to women for 1985-86. MIT expects that 22% of the 189 NSF Fellows studying at MIT next year will be women. This is only a slight increase from 20% in 1984-85. Traditionally more new NSF Fellows indicate MIT as their
institution for graduate study, it is interesting to note that in this year's competition MIT also
headed the list as first choice for women to pursue their graduate work. The ONR competition is
only in its third year and next year we expect four women ONR Fellows at MIT. Although the total
number of women who receive these awards is not equal to the number of men, it is partially due
to the fact that women are still in the minority in the fields of study where MIT's largest student
population lies. We hope that as more women are encouraged to participate in traditionally male-
dominated areas so will their proportion of the awards at MIT.

On the other hand, women pursuing graduate study at MIT are supported not only as RA's and TA's
in growing numbers by their respective departments, but increasingly are being sponsored by industrial
fellowships such as Hughes, Aerospace, Bell Labs Fellowships (for employees), Digital, IBM, Shell,
and Chevron. Also, two of the five prestigious EXXON Teaching Fellowships have been held by women.
The few national scholarship programs specifically for women graduate students are also well represented
at MIT including American Association of University Women Dissertation Fellowships, Graduate Research
Program for Women sponsored by the Bell Laboratories, Xerox Special Opportunities Fellowship Program,
and the IBM Fellowship Program for Women and Minorities. MIT's only financial aid program primarily
for women - the Ida M. Green Fellowships - has recently selected six additional women who will
be entering graduate programs in the Fall. This brings to 89 the number of women graduate students
so honored. Many have completed their degree programs at MIT and have earned 19 doctoral degrees,
19 Master's degrees (including three Master of Architecture and two Master of City Planning degrees),
and one Engineer's degree. Most are now pursuing lucrative careers in industry, academia, and
government with a few who left MIT with Master's degrees continuing their graduate study at other
universities. These women are representative of the truly outstanding caliber of women who attend
MIT and most of MIT's 21 graduate departments are represented by at least one Ida Green Fellow.
Therefore, it is important that we continue to encourage an even larger number of women to matriculate
in our graduate school by making sure financial as well as academic support is available to them.

JEANNE E. RICHARD
While black Americans have made dramatic educational gains since 1960, these gains have eroded in the last decade, and current social, economic, and policy trends threaten to wipe them out.

A new report from the College Board, "Equality and Excellence: The Educational Status of Black Americans," highlights these critical trends in demographic income and employment, educational status, and public policy affecting access to education and academic success for black students. The report notes the following significant findings on the education of blacks:

- College attendance and completion rates for blacks have dropped since 1975, despite improved high school graduation rates over the past two decades.

- Black students are "seriously underrepresented" in graduate and professional schools, and their participation in postgraduate education has declined since the early 1970's.

- Compared with all students, blacks continually lose ground in their progress through the educational pipeline. For example, in 1972 blacks represented 12.7 percent of all 18-year-olds, 10.5 percent of all 1972 high school graduates, 8.7 percent of all college freshmen, and four years later, 6.5 percent of all bachelor’s degree recipients. By 1979, blacks represented only about 4 percent of all professional and doctoral degree recipients. These serious problems of educational access and attainment for blacks and other underrepresented minority racial groups are likely to be exacerbated in the coming years. Educators and policy-makers who are concerned about equality, as well as fundamental excellence, must put these issues and others back in the forefront of the nation's attention.

The national picture does point a discouraging backdrop against the ongoing and positive efforts of the Institute in identifying, attracting, and graduating minority graduate students. If fewer minority students are graduating from College, then we will have fewer minority students in our applicant pool and consequently, fewer students to enroll in graduate school and graduate with master’s and doctor’s degrees. Table XV at the end of this report on Minority Applicants Admitted and Enrolled show that we had a 8% decline in minority applications for the fall term of 1984-85, moving from 170 applications in 1983 to 156 in 1984. These fewer applications produced fewer students admitted for 1984 (64) and fewer students enrolled (141 for 1984) as reflected in Table XIII.

MIT has to expend more time, energy, and funds just to keep pace with what we accomplished the previous year in minority graduate student presence at the Institute. Table XIV shows that the trend in minority graduate student enrollment over the past four years has leveled off at approximately 140 students while correspondingly, the total graduate enrollment has also leveled off at 4600 students. Even though our enrollment of minority graduate students has leveled off MIT still graduates the largest number of minority students with graduate degrees in science and engineering in the country (see Table XVI on Minority Graduate Degree Recipients).

The Office of the Dean of the Graduate School, along with the assistance of the Black Graduate Student Association, were able to sponsor a number of activities during the course of the year which helped to introduce and integrate the new minority graduate student into the mainstream of the Institute. These services and activities helped facilitate the smooth and unencumbered adjustment of minority graduate students, faculty, and staff to the pace and style that is unique to MIT. Some of these activities are listed below:

- Minority Graduate Student Orientation Program
- Recruitment trips to identify new students, 23 undergraduate schools were visited by minority graduate students to their alma mater, faculty members, and Dean Turner
- Fall and spring retreats to Talbot House in Vermont
- Published the 65-page booklet, 1984-85 Minority Graduate Student Guide
- Monthly Informal Discussion Sessions with invited guest speakers
- Social Gatherings (Parties)
- A month-long activities in conjunction with Black History Month (February, with such activities as art shows, poetry reading, showing of documentaries, lectures by Nikki Giovanni, Julian Bond, etc.)
- Ebony Affair semi-formal dance and cabaret
- Minority Awards Day Program
- Reception for the Class of 1985 and Parents
Let us all clearly understand the nature of the challenge before us to make graduate education accessible to all. Unless we act now we will endanger America's future. By taking action, we will have accomplished far more than a major objective for higher education. We will have rekindled the torch and kept alive the light of intellectual energy and moral sensibility that holds back the darkness from our world.

JOHN B. TURNER
TABLE I

For simple comparison with data for 1983-84, the following statistical information for 1984-85 is presented in the same format. Numbers in parenthesis indicate the change from 1983-84 to 1984-85.

REGULAR GRADUATE STUDENT ENROLLMENT - FALL TERM 1984

<table>
<thead>
<tr>
<th>School of Architecture and Planning</th>
<th>Foreign (1)</th>
<th>Women (2)</th>
<th>Minority (3)</th>
<th>Total</th>
<th>Non-Resident (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Engineering</td>
<td>117 (-8)</td>
<td>179 (+8)</td>
<td>26 (-9)</td>
<td>439 (+13)</td>
<td>48 (+2)</td>
</tr>
<tr>
<td>School of Humanities and Social Science</td>
<td>772 (-3)</td>
<td>295 (+55)</td>
<td>58 (-2)</td>
<td>2272 (+68)</td>
<td>9 (-4)</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>90 (-5)</td>
<td>109 (+13)</td>
<td>13 (-1)</td>
<td>399 (+14)</td>
<td>70 (+5)</td>
</tr>
<tr>
<td>School of Science</td>
<td>169 (+18)</td>
<td>114 (-15)</td>
<td>18 (+11)</td>
<td>522 (+15)</td>
<td>9 (-3)</td>
</tr>
<tr>
<td>Health Science and Technology</td>
<td>2 (-2)</td>
<td>3 (N.C.)</td>
<td>0 (-1)</td>
<td>23 (-4)</td>
<td>0</td>
</tr>
<tr>
<td>Health Policy and Management</td>
<td>0</td>
<td>2 (+1)</td>
<td>0</td>
<td>7 (+4)</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1449 (+10)</td>
<td>981 (+67)</td>
<td>141 (-2)</td>
<td>4757 (+126)</td>
<td>154 (-5)</td>
</tr>
</tbody>
</table>

(1) Includes Canadians  
(2) See also Table IX  
(3) Includes Black Americans, Puerto Ricans, Mexican Americans and American Indians  
(4) Included in Totals
TABLE II

GRADUATE DEGREES AWARDED - 1984-85

<table>
<thead>
<tr>
<th>Advanced Degrees Conferred</th>
<th>M.C.P., 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 1984</td>
<td>4 (-3)</td>
<td>135 (-19)</td>
<td>13 (N.C.)</td>
<td>5 (-3)</td>
<td>94 (+15)</td>
<td>255 (-11)</td>
</tr>
<tr>
<td></td>
<td>Woods Hole</td>
<td>0 (N.C.)</td>
<td>0 (-2)</td>
<td>0 (N.C.)</td>
<td>4 (+1)</td>
<td></td>
</tr>
<tr>
<td>February 1985</td>
<td>14 (+3)</td>
<td>237 (-19)</td>
<td>8 (-13)</td>
<td>11 (-4)</td>
<td>135 (+12)</td>
<td>408 (-22)</td>
</tr>
<tr>
<td></td>
<td>Woods Hole</td>
<td>0 (N.C.)</td>
<td>0 (N.C.)</td>
<td>4 (-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 1985</td>
<td>49 (-8)</td>
<td>616 (+13)</td>
<td>35 (-3)</td>
<td>27 (+6)</td>
<td>162 (+6)</td>
<td>894 (+16)</td>
</tr>
<tr>
<td></td>
<td>Woods Hole</td>
<td>0 (N.C.)</td>
<td>0 (-1)</td>
<td>5 (+3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>66 (-9)</td>
<td>988 (-24)</td>
<td>56 (-16)</td>
<td>43 (-4)</td>
<td>404 (+36)</td>
<td>1557 (-17)</td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate change from 1983-84
<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Arch. (Citizen)</th>
<th>Arch. (Foreign)</th>
<th>Eng'g. (Citizen)</th>
<th>Eng'g. (Foreign)</th>
<th>Hum. and Soc. Sci. (Citizen)</th>
<th>Hum. and Soc. Sci. (Foreign)</th>
<th>Sloan (Citizen)</th>
<th>Sloan (Foreign)</th>
<th>Science (Citizen)</th>
<th>Science (Foreign)</th>
<th>HST (Citizen)</th>
<th>HST (Foreign)</th>
<th>Total (Citizen)</th>
<th>Total (Foreign)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-75</td>
<td>7 (.037)</td>
<td>2 (.033)</td>
<td>104 (.095)</td>
<td>56 (.107)</td>
<td>31 (.143)</td>
<td>10 (.154)</td>
<td>10 (.040)</td>
<td>8 (.080)</td>
<td>110 (.110)</td>
<td>24 (.110)</td>
<td></td>
<td></td>
<td>262 (.105)</td>
<td>100 (.103)</td>
<td>362</td>
</tr>
<tr>
<td>1975-76</td>
<td>1 (.005)</td>
<td>1 (.019)</td>
<td>83 (.073)</td>
<td>67 (.114)</td>
<td>49 (.232)</td>
<td>7 (.119)</td>
<td>12 (.055)</td>
<td>2 (.017)</td>
<td>126 (.162)</td>
<td>42 (.180)</td>
<td></td>
<td></td>
<td>271 (.106)</td>
<td>119 (.113)</td>
<td>390</td>
</tr>
<tr>
<td>1976-77</td>
<td>6 (.026)</td>
<td>4 (.071)</td>
<td>79 (.068)</td>
<td>64 (.106)</td>
<td>33 (.155)</td>
<td>19 (.264)</td>
<td>2 (.007)</td>
<td>1 (.010)</td>
<td>125 (.156)</td>
<td>46 (.199)</td>
<td></td>
<td></td>
<td>265 (.090)</td>
<td>134 (.126)</td>
<td>390</td>
</tr>
<tr>
<td>1977-78</td>
<td>5 (.023)</td>
<td>3 (.039)</td>
<td>111 (.096)</td>
<td>66 (.103)</td>
<td>50 (.240)</td>
<td>13 (.169)</td>
<td>8 (.029)</td>
<td>3 (.029)</td>
<td>119 (.146)</td>
<td>35 (.141)</td>
<td></td>
<td></td>
<td>293 (.110)</td>
<td>132 (.115)</td>
<td>425</td>
</tr>
<tr>
<td>1978-79</td>
<td>10 (.041)</td>
<td>3 (.033)</td>
<td>80 (.066)</td>
<td>64 (.101)</td>
<td>35 (.164)</td>
<td>11 (.130)</td>
<td>10 (.035)</td>
<td>9 (.088)</td>
<td>126 (.151)</td>
<td>33 (.142)</td>
<td></td>
<td></td>
<td>261 (.093)</td>
<td>120 (.105)</td>
<td>381</td>
</tr>
<tr>
<td>1979-80</td>
<td>8 (.031)</td>
<td>3 (.034)</td>
<td>96 (.074)</td>
<td>66 (.096)</td>
<td>40 (.156)</td>
<td>11 (.109)</td>
<td>5 (.017)</td>
<td>3 (.029)</td>
<td>127 (.153)</td>
<td>28 (.115)</td>
<td></td>
<td></td>
<td>276 (.094)</td>
<td>111 (.091)</td>
<td>387</td>
</tr>
<tr>
<td>1980-81</td>
<td>12 (.044)</td>
<td>7 (.078)</td>
<td>88 (.065)</td>
<td>75 (.103)</td>
<td>40 (.178)</td>
<td>12 (.153)</td>
<td>7 (.022)</td>
<td>2 (.020)</td>
<td>118 (.138)</td>
<td>33 (.130)</td>
<td></td>
<td></td>
<td>265 (.088)</td>
<td>131 (.104)</td>
<td>396</td>
</tr>
<tr>
<td>1981-82</td>
<td>7 (.023)</td>
<td>2 (.017)</td>
<td>94 (.066)</td>
<td>75 (.104)</td>
<td>35 (.128)</td>
<td>21 (.223)</td>
<td>4 (.012)</td>
<td>6 (.050)</td>
<td>124 (.148)</td>
<td>35 (.123)</td>
<td></td>
<td></td>
<td>264 (.083)</td>
<td>139 (.103)</td>
<td>399</td>
</tr>
<tr>
<td>1982-83</td>
<td>6 (.026)</td>
<td>4 (.027)</td>
<td>93 (.070)</td>
<td>78 (.102)</td>
<td>43 (.189)</td>
<td>14 (.150)</td>
<td>11 (.031)</td>
<td>2 (.016)</td>
<td>126 (.160)</td>
<td>52 (.184)</td>
<td></td>
<td></td>
<td>280 (.096)</td>
<td>152 (.107)</td>
<td>403</td>
</tr>
<tr>
<td>1983-84</td>
<td>9 (.035)</td>
<td>5 (.040)</td>
<td>92 (.065)</td>
<td>76 (.098)</td>
<td>41 (.182)</td>
<td>16 (.168)</td>
<td>12 (.035)</td>
<td>9 (.059)</td>
<td>115 (.150)</td>
<td>37 (.128)</td>
<td></td>
<td></td>
<td>272 (.089)</td>
<td>163 (.099)</td>
<td>415</td>
</tr>
<tr>
<td>1984-85</td>
<td>10 (.031)</td>
<td>3 (.026)</td>
<td>111 (.074)</td>
<td>76 (.098)</td>
<td>32 (.104)</td>
<td>15 (.167)</td>
<td>7 (.019)</td>
<td>11 (.065)</td>
<td>128 (.161)</td>
<td>50 (.167)</td>
<td></td>
<td></td>
<td>291 (.088)</td>
<td>156 (.108)</td>
<td>447</td>
</tr>
</tbody>
</table>

**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 IV
A "SNAPSHOT" OF GRADUATE STUDENT SUPPORT "FULL AWARDS"
FALL TERM 1984

The following sources provided at least full tuition support for graduate students during the Fall Term 1984. Total regular graduate student enrollment, not including Non-Residents, was 4,603.

<table>
<thead>
<tr>
<th>FELLOWSHIPS AND TRAINEESHIPS AWARDED BY MIT</th>
<th>Numbers of Students</th>
<th>Percent of Total Enrollment</th>
<th>Change from 1983-84</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIH and NIMH Traineeships</td>
<td>94</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>HEW Graduate and Professional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunities Program Fellowships</td>
<td>12</td>
<td>+ 7</td>
<td></td>
</tr>
<tr>
<td>MIT Endowed and Other Fund Fellowships</td>
<td>179</td>
<td>- 9</td>
<td></td>
</tr>
<tr>
<td>Industrial and Foundation Fellowships</td>
<td>182</td>
<td>-27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>467</td>
<td>10%</td>
<td>-39</td>
</tr>
<tr>
<td>FELLOWSHIPS AWARDED BY SPONSORS TO MIT STUDENTS</td>
<td>170</td>
<td>+22</td>
<td></td>
</tr>
<tr>
<td>NSF Graduate Fellowships</td>
<td>4</td>
<td>N.C.</td>
<td></td>
</tr>
<tr>
<td>NIMH Fellowships</td>
<td>33</td>
<td>+ 6</td>
<td></td>
</tr>
<tr>
<td>ONR Fellowships</td>
<td>13</td>
<td>+ 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>220</td>
<td>4.8%</td>
<td>+33</td>
</tr>
<tr>
<td>STUDENT ASSISTANTSHIPS</td>
<td>1571</td>
<td>+195</td>
<td></td>
</tr>
<tr>
<td>Research Assistants</td>
<td>390</td>
<td>+ 1</td>
<td></td>
</tr>
<tr>
<td>Instructor G</td>
<td>5</td>
<td>- 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1966</td>
<td>43%</td>
<td>+188</td>
</tr>
<tr>
<td>SPONSORED STUDENTS</td>
<td></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 arrangements:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. Government</td>
<td>120</td>
<td>-14</td>
<td></td>
</tr>
<tr>
<td>Foreign Countries and International Programs</td>
<td>154</td>
<td>-14</td>
<td></td>
</tr>
<tr>
<td>Industry and Foundation (U.S.)</td>
<td>91</td>
<td>-19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>365</td>
<td>8%</td>
<td>-47</td>
</tr>
<tr>
<td>SUMMARY BY SOURCES - FULL AWARDS</td>
<td>289</td>
<td>6%</td>
<td>+ 24</td>
</tr>
<tr>
<td>Federal Fellowships and Traineeships</td>
<td>1966</td>
<td>43%</td>
<td>+218</td>
</tr>
<tr>
<td>Graduate Student Staff</td>
<td>215</td>
<td>5%</td>
<td>- 21</td>
</tr>
<tr>
<td>Industrial and Foundation Awards</td>
<td>179</td>
<td>4%</td>
<td>- 9</td>
</tr>
<tr>
<td>MIT Endowed and Budgeted Funds</td>
<td>365</td>
<td>8%</td>
<td>- 47</td>
</tr>
<tr>
<td>Students Sponsored by External Sources</td>
<td>3014</td>
<td>66%</td>
<td>+165</td>
</tr>
</tbody>
</table>
TABLE V

DISTRIBUTION OF FUNDING FOR GRADUATE STUDENT TUITION AND LIVING EXPENSES
FALL TERM 1984

### Estimates of Required Funding

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition</td>
<td>22,950,051</td>
</tr>
<tr>
<td>Stipend (865/mo. for 4½ months)</td>
<td>17,356,296</td>
</tr>
<tr>
<td><strong>Total Estimated Required Funding</strong></td>
<td>40,306,347</td>
</tr>
</tbody>
</table>

### Identified Support by Category

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Assistantships</td>
<td>13,993,675</td>
<td>(34.5%)</td>
</tr>
<tr>
<td>Teaching Assistantships</td>
<td>3,934,835</td>
<td>(9.8%)</td>
</tr>
<tr>
<td>Federal Fellowships and Traineeships</td>
<td>2,357,589</td>
<td>(6%)</td>
</tr>
<tr>
<td>General and Endowed Support (departmentally controlled)</td>
<td>1,512,212</td>
<td>(3.6%)</td>
</tr>
<tr>
<td>General and Endowed Support (Graduate School Office controlled)</td>
<td>639,747</td>
<td>(1.5%)</td>
</tr>
<tr>
<td>Outside Sources Administered by Departments</td>
<td>1,501,645</td>
<td>(3%)</td>
</tr>
<tr>
<td>Outside Sources Administered by Graduate School Office</td>
<td>746,078</td>
<td>(1.5%)</td>
</tr>
<tr>
<td>Outside Sources, Direct Billing to Sponsor by Institute, Tuition Only</td>
<td>1,944,295</td>
<td>(5%)</td>
</tr>
<tr>
<td><strong>Total Identified Support</strong></td>
<td>26,630,076</td>
<td>(66%)</td>
</tr>
<tr>
<td>Loans</td>
<td>4,410,474</td>
<td>(11%)</td>
</tr>
</tbody>
</table>
TABLE VI
TRENDS IN GRADUATE STUDENT SUPPORT
($000's)

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Fellowships (Staff Tuition Awards (TA &amp; IG))</th>
<th>Loans</th>
<th>Including Outside Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scholarships*</td>
<td>483 (.059)</td>
<td>672 (.082)</td>
</tr>
<tr>
<td>1970-71</td>
<td>5,396 (.655)</td>
<td>4,850 (.831)</td>
<td></td>
</tr>
<tr>
<td>1971-72</td>
<td>5,076 (.589)</td>
<td>5,086 (.823)</td>
<td></td>
</tr>
<tr>
<td>1972-73</td>
<td>4,687 (.486)</td>
<td>7,991 (.828)</td>
<td></td>
</tr>
<tr>
<td>1973-74</td>
<td>3,930 (.378)</td>
<td>1,453 (.140)</td>
<td></td>
</tr>
<tr>
<td>1974-75</td>
<td>3,693 (.318)</td>
<td>9,760 (.840)</td>
<td></td>
</tr>
<tr>
<td>1975-76</td>
<td>3,447 (.259)</td>
<td>10,878 (.816)</td>
<td></td>
</tr>
<tr>
<td>1976-77</td>
<td>3,454 (.229)</td>
<td>11,654 (.722)</td>
<td></td>
</tr>
<tr>
<td>1977-78</td>
<td>3,418 (.205)</td>
<td>12,479 (.750)</td>
<td></td>
</tr>
<tr>
<td>1978-79</td>
<td>3,667 (.198)</td>
<td>15,251 (.823)</td>
<td></td>
</tr>
<tr>
<td>1979-80</td>
<td>3,733 (.172)</td>
<td>16,610 (.766)</td>
<td></td>
</tr>
<tr>
<td>1980-81</td>
<td>3,970 (.149)</td>
<td>18,650 (.702)</td>
<td></td>
</tr>
<tr>
<td>1981-82</td>
<td>4,194 (.128)</td>
<td>21,258 (.648)</td>
<td></td>
</tr>
<tr>
<td>1982-83</td>
<td>5,142 (.136)</td>
<td>21,993 (.581)</td>
<td></td>
</tr>
<tr>
<td>1983-84</td>
<td>5,561 (.130)</td>
<td>12,671 (.295)</td>
<td></td>
</tr>
<tr>
<td>1984-85</td>
<td>6,516 (.137)</td>
<td>14,131 (.298)</td>
<td></td>
</tr>
</tbody>
</table>

*Administered by the Graduate School Office

**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 - 1983 & 1984

<table>
<thead>
<tr>
<th>School of Architecture &amp; Planning</th>
<th>1983</th>
<th>1984</th>
<th>1983 %</th>
<th>1984 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture IV</td>
<td>80</td>
<td>87</td>
<td>33%</td>
<td>35.5%</td>
</tr>
<tr>
<td>Urban Studies &amp; Planning XI</td>
<td>91</td>
<td>92</td>
<td>49%</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>171</td>
<td>179</td>
<td>40%</td>
<td>41%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School of Engineering</th>
<th>1983</th>
<th>1984</th>
<th>1983 %</th>
<th>1984 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautics &amp; Astronautics XVI</td>
<td>14</td>
<td>21</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td>Chemical Engineering X</td>
<td>32</td>
<td>34</td>
<td>15%</td>
<td>16%</td>
</tr>
<tr>
<td>Civil Engineering I</td>
<td>25</td>
<td>29</td>
<td>11%</td>
<td>13%</td>
</tr>
<tr>
<td>Elec. Engineering &amp; Comp. Science VI, A, W</td>
<td>77</td>
<td>104</td>
<td>12.5%</td>
<td>16%</td>
</tr>
<tr>
<td>Materials Science III, III-B, III-W</td>
<td>43</td>
<td>42</td>
<td>18%</td>
<td>17%</td>
</tr>
<tr>
<td>Mechanical Engineering II, II-T, II-W</td>
<td>28</td>
<td>40</td>
<td>7%</td>
<td>9%</td>
</tr>
<tr>
<td>Nuclear Engineering XXII</td>
<td>13</td>
<td>17</td>
<td>8%</td>
<td>10%</td>
</tr>
<tr>
<td>Ocean Engineering XIII, XIII-A, XIII-B</td>
<td>6</td>
<td>6</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>22%</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>240</td>
<td>295</td>
<td>11%</td>
<td>13%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School of Humanities &amp; Social Sciences</th>
<th>1983</th>
<th>1984</th>
<th>1983 %</th>
<th>1984 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics XIV</td>
<td>18</td>
<td>14</td>
<td>15%</td>
<td>11%</td>
</tr>
<tr>
<td>Linguistics &amp; Philosophy XXIV</td>
<td>23</td>
<td>30</td>
<td>39%</td>
<td>48%</td>
</tr>
<tr>
<td>Political Science XVII</td>
<td>44</td>
<td>53</td>
<td>26%</td>
<td>30%</td>
</tr>
<tr>
<td>Psychology IX</td>
<td>11</td>
<td>12</td>
<td>34%</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>109</td>
<td>25%</td>
<td>27%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sloan School of Management</th>
<th>1983</th>
<th>1984</th>
<th>1983 %</th>
<th>1984 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management XV</td>
<td>118*</td>
<td>91</td>
<td>27%*</td>
<td>24%</td>
</tr>
<tr>
<td>XV-P</td>
<td>13</td>
<td></td>
<td></td>
<td>16.6%</td>
</tr>
<tr>
<td>XV-A (Fellows)</td>
<td>8</td>
<td>6</td>
<td>14%</td>
<td>10.5%</td>
</tr>
<tr>
<td>XV-B (Operations Research)</td>
<td>3</td>
<td>4</td>
<td>33%</td>
<td>26.6%</td>
</tr>
<tr>
<td></td>
<td>129</td>
<td>114</td>
<td>25%</td>
<td>22%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School of Science</th>
<th>1983</th>
<th>1984</th>
<th>1983 %</th>
<th>1984 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>***Applied Biological Sciences XX</td>
<td>62</td>
<td>52</td>
<td>46%</td>
<td>44%</td>
</tr>
<tr>
<td>Biology VII</td>
<td>45</td>
<td>48</td>
<td>34%</td>
<td>33.3%</td>
</tr>
<tr>
<td>VII-W</td>
<td>13</td>
<td>12</td>
<td>59%</td>
<td>60%</td>
</tr>
<tr>
<td>Chemistry V</td>
<td>49</td>
<td>57</td>
<td>28%</td>
<td>27.5%</td>
</tr>
<tr>
<td>**Earth, Atmospheric, &amp; Planetary Science XII</td>
<td>22</td>
<td>22</td>
<td>17%</td>
<td>19%</td>
</tr>
<tr>
<td>XII-W</td>
<td>26</td>
<td>23</td>
<td>42%</td>
<td>38%</td>
</tr>
<tr>
<td>Mathematics XVIII</td>
<td>22</td>
<td>26</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Physics VIII</td>
<td>35</td>
<td>39</td>
<td>12%</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>274</td>
<td>279</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>HST</td>
<td>3</td>
<td>3</td>
<td>11%</td>
<td>13%</td>
</tr>
<tr>
<td>HPM</td>
<td>1</td>
<td>2</td>
<td>33%</td>
<td>28.5%</td>
</tr>
<tr>
<td>TOTALS</td>
<td>914</td>
<td>981</td>
<td>20%</td>
<td>21%</td>
</tr>
</tbody>
</table>

*Figures include totals for XV & XV-P
**Figures include former Crse XIX & XIX-W
***Formerly Nutrition & Food Science
TABLE VIII
Women Graduate Student Enrollment
(\% of total 1974-84)

<table>
<thead>
<tr>
<th>Fall Term</th>
<th>New Women</th>
<th>Total</th>
<th>% of Women</th>
<th>Continuing Women</th>
<th>Total</th>
<th>% of Women</th>
<th>Total 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>
</tbody>
</table>
### TABLE IX

**COMPARISON OF ADMISSIONS STATISTICS FOR GRADUATE WOMEN AND GRADUATE MEN**

**Number of Applicants 1983/Number of Applicants 1984**

Numbers in parentheses indicate the % change in number of applicants from 1982 to 1983

<table>
<thead>
<tr>
<th>School of Architecture &amp; Planning</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>260/309 (+18%)</td>
<td>518/393 (-24%)</td>
</tr>
<tr>
<td>School of Engineering</td>
<td>345/376 (+9%)</td>
<td>3147/2926 (-7%)</td>
</tr>
<tr>
<td>School of Humanities &amp; Social Science</td>
<td>191/199 (+4%)</td>
<td>482/496 (+3%)</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>371/331 (-11%)</td>
<td>1452/1408 (-3%)</td>
</tr>
<tr>
<td>School of Science</td>
<td>437/432 (-1%)</td>
<td>1241/1276 (+3%)</td>
</tr>
<tr>
<td>HST</td>
<td>8/12 (+50%)</td>
<td>38/24 (-37%)</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>1612/1659 (+3%)</td>
<td>6878/6523 (-5%)</td>
</tr>
</tbody>
</table>
### Table X
Comparison of Women Enrolled with Women Degree Recipients, 1984-85

<table>
<thead>
<tr>
<th>Discipline</th>
<th>% of Women Enrolled</th>
<th>% of Degrees awarded to Women Master's</th>
<th>% of Degrees awarded to Women Doctoral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture &amp; Planning</td>
<td>41% (179/439) (40%)</td>
<td>42% (48/115) (41%)</td>
<td>54% (7/13) (14%)</td>
</tr>
<tr>
<td>Engineering</td>
<td>13% (295/2,272) (11%)</td>
<td>12% (77/641) (12%)</td>
<td>8% (15/183) (4%)</td>
</tr>
<tr>
<td>Humanities &amp; Social Science</td>
<td>27% (109/399) (25%)</td>
<td>4% (7/16) (9%)</td>
<td>30% (14/47) (35%)</td>
</tr>
<tr>
<td>Sloan School of Management</td>
<td>22% (114/522) (25%)</td>
<td>23% (58/252) (24.5%)</td>
<td>11% (2/18) (19%)</td>
</tr>
<tr>
<td>Science</td>
<td>25% (279/1,095) (25%)</td>
<td>19% (6/31) (35%)</td>
<td>23% (39/168) (18%)</td>
</tr>
<tr>
<td>HST</td>
<td>13% (3/23) (11%)</td>
<td>25% (1/4) (0%)</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>21% (20%)</td>
<td>19% (199/1,055) (19%)</td>
<td>18% (78/446) (15%)</td>
</tr>
</tbody>
</table>

ALL DEGREES: 18% (277/1,557) (18%)

(%) = 1983-84 figures
<table>
<thead>
<tr>
<th>Table XI</th>
<th>Degrees Awarded to Women by School</th>
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<td>3</td>
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<tr>
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<td>Doctor's</td>
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*M.Arch., MCP, SM
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<td>1974-75</td>
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<td>32</td>
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<tr>
<td>1975-76</td>
<td>93</td>
<td>862</td>
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<td>971</td>
<td>15%</td>
<td>50</td>
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<tr>
<td>1977-78</td>
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<td>934</td>
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<td>968</td>
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<td>1981-82</td>
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<td>1982-83</td>
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<td>1124</td>
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<td>1983-84</td>
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*Without Engineer's Degrees*
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<th>AI</th>
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<th>TOTAL OF ALL GRADUATE STUDENTS</th>
<th>% OF TOTAL</th>
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<td>2 (1)</td>
<td>3 (2)</td>
<td>2 (1)</td>
<td>26 (9)</td>
<td>391</td>
<td>6.6%</td>
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<td>2</td>
<td>3 (2)</td>
<td>1 (1)</td>
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<td>426</td>
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<td></td>
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<td>8</td>
<td>8 (4)</td>
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<td>2263</td>
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<td>1</td>
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<td>4 (2)</td>
<td>2 (1)</td>
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<td>Total Minority Graduate Students</td>
<td>Total Of All Graduate Students</td>
<td>% Of Total</td>
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<td></td>
<td>3</td>
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<td></td>
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<td>3</td>
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<td><strong>141 (42)</strong></td>
<td><strong>4603</strong></td>
<td><strong>3.1%</strong></td>
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</tbody>
</table>

( ) = New Students
BA = Black American
PR = Puerto Rican
MA = Mexican American
AI = American Indian

---

TABLE XIII (continued)
### TABLE XIV

**Trends in Minority Graduate Enrollment at MIT**

<table>
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<td>62</td>
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<td>16</td>
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<td>25</td>
<td>28</td>
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<td>Total Minority Enrollment</td>
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<td>157</td>
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<td>144</td>
<td>171</td>
<td>140</td>
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<td>12</td>
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<td>8</td>
<td>5</td>
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<td>20</td>
<td>20</td>
<td>16</td>
<td>17</td>
<td>18</td>
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</tr>
<tr>
<td>Total Black Enrollment</td>
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<td>119</td>
<td>130</td>
<td>114</td>
<td>111</td>
<td>104</td>
<td>121</td>
<td>97</td>
<td>93+</td>
<td>99</td>
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</table>

* Totals include one black graduate student registered in the HST Program.

* Does not include Special or Non-Resident Graduate Student Enrollment.
TABLE XV
Minority* Applicants Admitted and Enrolled
1983-84 vs 1984-85

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<td></td>
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<td>Ad</td>
<td>Enrolled</td>
<td>Rec'd</td>
<td>Ad</td>
<td>Enrolled</td>
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<td>9</td>
<td>11</td>
<td>8</td>
<td>6</td>
</tr>
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<td>12</td>
<td>12</td>
<td>20</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
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<td>3</td>
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<td>2</td>
<td>3</td>
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<td>0</td>
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<td>9</td>
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<td>2</td>
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<td>Nuclear Engineering (XXII)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Ocean Engineering (XIII, XIII-W, XIII-A, XIII-B)</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td>63</td>
<td>26</td>
<td>23</td>
<td>61</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Sloan School of Management (XV, XV-A, XV-B)</td>
<td>43</td>
<td>19</td>
<td>3</td>
<td>45</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Humanities &amp; Social Sciences</td>
<td></td>
<td></td>
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<td>2</td>
<td>7</td>
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<td>1</td>
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<tr>
<td>Linguistics &amp; Philosophy (XXIV)</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>Political Science (XVII)</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Psychology (IX)</td>
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<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>6</td>
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<td>13</td>
<td>7</td>
<td>5</td>
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<td>Science</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Biology (VII, VII-W)</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Chemistry (V)</td>
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<td>1</td>
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<td>3</td>
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<td>0</td>
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<tr>
<td>Earth, Atmospheric &amp; Planetary Sciences (XII, XII-W)</td>
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<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Mathematics (XVIII)</td>
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<td>1</td>
</tr>
<tr>
<td>Applied Biological Sciences (XX)</td>
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<td>1</td>
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<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(formerly Nutrition &amp; Food Sciences)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics (VIII)</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>10</td>
<td>6</td>
<td>17</td>
<td>6</td>
<td>2</td>
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<tr>
<td>Totals</td>
<td>170</td>
<td>73</td>
<td>49</td>
<td>156</td>
<td>64</td>
<td>42</td>
</tr>
</tbody>
</table>

*Minority - refers to four underrepresented racial groups:
Black American, Mexican American, Puerto Rican, Native American.
### TABLE XVI

**Minority Graduate Degree Recipients**

*1984-85*

(September, February, June Degree Lists)

<table>
<thead>
<tr>
<th>Degree List</th>
<th>Black</th>
<th>Hispanic*</th>
<th>Native American</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master's</td>
<td>20</td>
<td>3</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Engineer's</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Doctor's</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>8</td>
<td>2</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Degree List</th>
<th>Master's</th>
<th>Engineer's</th>
<th>Doctor's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>HS*</td>
<td>NA</td>
</tr>
<tr>
<td>September</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>February</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>13</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

B = Black American  
HS* = Hispanic (Mexican American & Puerto Rican)  
NA = Native American
This is the last year in which the Report of the Dean for Student Affairs will appear in this section of the Reports to the President. As part of this summer's reorganization of the Provost's Office, Dr. Shirley M. McBay, the Dean for Student Affairs, will be one of three Deans reporting to Professor Samuel Jay Keyser, the new Associate Provost for Educational Programs and Policy. The other two deans are Professor Frank E. Perkins, Dean of the Graduate School, and Professor Margaret L. A. MacVicar, who will be MIT's first Dean for Undergraduate Education. These structural changes are a part of a major and very positive thrust launched by our new Provost, Professor John M. Deutch, to conduct a review and assessment of all aspects of undergraduate education at MIT as they affect our students, both inside and outside the classroom. The review will center on faculty activities conducted through the five Schools and through the central Faculty Committees. The Committee structure was also reorganized this spring to provide for clear and more substantive and manageable involvement of the Faculty in policy development.

To be successful, the review of undergraduate education must receive full support from all of the administrative offices and the services that relate to students throughout the university. Professor Keyser and his associates in the Office of the Provost provide an ideal team to lead this exciting new venture. At a meeting of the Dean's staff following Commencement in June, I expressed my own personal enthusiasm at the new arrangements for educational leadership and for continued reform. I would like to take this opportunity to reiterate my confidence in the quality, the talent, and the dedication of the Student Affairs staff. It is, in my view, a very strong group, and much of the credit for its strength belongs to the able and courageous leadership provided by Dean McBay. We will miss her lively presence at our weekly staff meetings, and all of us join to wish her and her colleagues continued success.

Last year we recruited and welcomed a new Director of Admissions; we established new bylaws and put in place a new governance for the Medical Department; we worked with the students on major policy changes which address external issues -- such as the new drinking age law -- and our own campus community standards -- such as the tolerance for pornographic movies. Counseling and advice on career plans and post-graduate study, and job interviews occupied the graduating students' attention during the spring. We helped to stage and service a large number of professional meetings on campus attended by thousands of MIT people and visitors; we designed, edited, and published many pages of catalogues and directories, many colorful, prize-winning posters, and 143 major scholarly books bearing the MIT imprint which found their way in global markets; we continued to field the largest number of collegiate varsity teams in the country and were, once again, in the national championship in women's volleyball. We inaugurated important benefit programs in the sheltering of pension payments, in automatic payroll deductions, and in flexible individual reimbursement accounts; we grappled with the challenges of five-year planning Institute-wide and with a frustrating lack of progress, despite our efforts, in minority recruitment, especially in the most crucial area of black and Hispanic faculty.

It has been a good year of hard work. No summary statement can characterize it. The reports which follow do greater justice to the kaleidoscope of events, achievements, and frustrations which took up the commitment and the energy of several hundred colleagues in the areas for which I am responsible.

The reports are accurate and complete accounts of what transpired. In their totality, however, these reports fail to capture the value of each one of a myriad of individual transactions, one-on-one interactions, in-depth consultations between dean and student, doctor and patient, personnel officer and fellow employee, manager and associate, coach and athlete. Throughout the university, but especially in those administrative units that are concerned with direct services to people, the individual case load is a characteristic and significant but illusive measure of achievement. For the weight of responsibility is not measured fully by the size of the staff or by the volume of dollars of the operation but, rather, by the influence -- we hope the positive influence -- exercised in each case where a staff member is called upon to help people cope with problems or to accomplish the aims they set for themselves in their work and in their personal lives. The ultimate measure of the quality of our services is not found in the frequency or even in the nature of these individual transactions but, rather, in the results and the effect, sometimes subtle, that each transaction has on its participants -- both the ones receiving and the ones giving help.

Leaders may struggle to improve their skills, their style, or their output. They may have clear goals and a sense of how to go about realizing them. But one of the toughest challenges of leadership in the people services is the challenge of measuring and improving the effectiveness of other people. Traditional standards of evaluation count only those things that can be counted. There are units of dollars spent, meetings attended, and papers shuffled. But there are no units of good judgment, no units of common sense, certainly no units of satisfaction to be stacked up against units of personal effort. There are no measurable units of good humor or perspective. But these are human qualities that make an important difference. They must be recognized and rewarded. Their absence leaves a gap in MIT's endowment of human capital. The presence
of these qualities in our staff lends richness, energy, and warmth to the life of all who study and work in this university.

And so my prefatory comment in this year's Report to the President is a recognition and a tribute to each of the women and the men in our midst who carry the case load of people issues and who give to the solution of each of these issues their best judgment and their best personal qualities. MIT is a better place to be because of their contributions.

CONSTANTINE B. SIMONIDES
The assessment and formulation of specific future actions of the affirmative action/equal opportunity program were the major thrusts of the 1984-85 year. The recognition of the poor performance with respect to the employment of minorities and women especially minority faculty, has presented a serious future challenge that requires a high priority on the part of our academic administration. The current workforce is 12 percent minority (five percent Black American, five percent Asian American, and two percent Hispanic American) and 88 percent non-minority, 37 percent female and 63 percent male. These statistics have not changed from last year and this continuation of no gains in the black and hispanic faculty and administrative staff clearly dictate a surge for new initiatives. Initial discussions on this important problem have been the central focus for the two key groups this past year, namely, the Equal Opportunity Staff Group and the Equal Opportunity Committee.

The Equal Opportunity Staff Group has developed a progressive plan to focus on increasing minority presence, especially blacks on the administrative staff. This group has begun discussions with three senior officers regarding: (1) how they assess the situation of black administrative presence in their areas, (2) their goals or special efforts to be made, (3) future strategies to increase black presence, and (4) possible means of assessing their process in affirmative action. These discussions have revitalized our spirit and there have already been some promising steps taken by these senior officers. While it is too early to fully evaluate this process, we have all the reason to be very optimistic based on the initial actions taken by these senior officers: Constantine Simonides, James Culliton, and William Dickson.

The second group, the Equal Opportunity Committee, is just beginning to explore ways that can assist academic departments in attracting minority and women faculty members. Progress in both of these categories have been unsatisfactory, especially the minority faculty representation. Initial steps by the new chairman, Institute Professor Herman Feshbach, give hope for future progress in increasing the representation of women and minorities on the faculty.

Beyond the above serious challenge facing the Institute there are two other activities that should be noted. First, we have successfully completed a compliance review by the Department of Labor. Second, the selection of Mr. Nelson Armstrong, Associate Director of the Admissions Office and Mr. Carl M. Julian, Layout Drafter of the Physical Plant Department, as MIT's representatives of the Black Achievers Program of the Greater Boston YMCA, was a highlight in our attempt to recognize outstanding performance in our black professional ranks of the Institute.

In conclusion, MIT continues to operate within a national mood of benign negligence as it relates to equity issues in education and employment for black and other minority Americans. However, our in-depth discussions within the Institute have provided optimism for positive affirmative action/equal opportunity activities during the next two years.
This past year there were a number of events and activities which epitomize the team approach to services provided by the Campus Information Services. Whether the project was a major conference, communications project, or policy matter, its success depended on the cooperation of the many individuals and offices within C.I.S. as well as among our offices and others at the Institute.

Highlights of the past year included logistical coordination for an unprecedented variety of events (including conferences, dedications, company visits, student visits, a naturalization ceremony for new U.S. citizens, and the largest Commencement in the history of the Institute); design and production of communications for a record number of Summer Session programs and design of new systems for many Alumni Association publications; completion of a survey and set of recommendations on typesetting needs and resources for the Institute; development of a prototype set of guidelines for staff performance evaluations; and greater attention to developing working relations and systems to enhance MIT's public image, particularly in support of admissions and development objectives.

High on the agenda for the coming year is this last point: the need to communicate more effectively with MIT's many publics -- prospective students, high schools, alumni, industry, the government, and the public at large -- in order to make the case for private higher education in general and for MIT in particular. This will require enhanced cooperation and planning among the staff in offices and departments throughout the Institute; the Campus Information Services looks forward to contributing to this effort.

KATHRYN W. LOMBARDI

In 1984-85 the Communications Office was involved in a number of special projects in addition to the production of its annual publications and consulting responsibilities within MIT.

We completed the Institute-wide survey of typesetting needs and capabilities, and disseminated the results and recommendations to appropriate members of the community. We obtained our results by surveying the offices of the academic departments and deans; 33 major laboratories, centers, and other academic programs; and 40 administrative offices.

In summary, we found that MIT's current publications procedures are not as cost-effective as they could be. However, with a number of modest but significant changes in procedures, we can get work accomplished more efficiently and for less money. Publications production is very decentralized at MIT, and many of our publications are handled by staff who are not professionally trained in the publishing field. There is a great disparity among the academic departments with regard to the kind of promotional materials they publish, and some MIT publications are both unattractive and disorganized. In addition, we found that the departments that have been most successful in presenting a unified look in their publications programs had assistance at some point from a professional graphic designer.

The survey results led to a number of recommendations which fell into three general categories:

1) MIT should make better use of current typesetting technology and equipment to achieve economies and improve quality in our operations. For example, greater use should be made of word processors and computers in preparing manuscripts, which could then be picked up electronically without rekey-boarding by a typesetter. As a follow-up to the survey, the Communications Office developed and distributed a list of typesetting firms in New England which can accept floppy disks or telecommunicated transmissions of copy from MIT clients.

2) We should make some improvements in the ways in which MIT purchases typesetting. For example, offices should obtain at least three bids from comparable suppliers, rather than simply awarding a job to the company that has done it before. Departments should be encouraged to do better planning for their publication needs, because too many areas are producing annual or cyclical publications on a "rush" schedule, resulting in premium prices and overtime charges. And, efforts should continue to inform the community about MIT resources which are available to assist in their publication plan-
ning and production.

3) We should review the level of quality that is appropriate for our publications, and determine how we can use them to market MIT more effectively. Currently, our publications present a somewhat confused image outside MIT, and this may well be creating problems in the ways in which MIT is perceived. In addition, we should consider using some new promotional materials to help address the enrollment imbalance.

A comprehensive report on the typesetting survey and a summary report are available in the Communications Office to anyone who is interested in the details of our findings.

Another project this year involved the development of a performance appraisal form for administrative staff members and their supervisors. The purpose of the form was to foster a constructive discussion about a staff member's job performance, including feedback about past accomplishments and expectations for future work. The goal of this effort was to encourage and improve communication about topics that are not always easy to discuss.

The idea of performance evaluations for staff members was a topic of discussion by managers reporting to the Vice President in the Office of the President. Several of these managers shared the procedures they have already established to evaluate and communicate with their staff-level employees. Three areas, the Office of the Dean for Student Affairs, Career Services and Preprofessional Advising, and CIS, volunteered to use their own form or the one that we developed on a trial basis in January. We hope that continued attention will be paid to the importance of communicating regularly with staff members about their performance.

We are currently working on a major revision of Policies and Procedures, which has not been published since September 1979. John M. Wynne, retired Vice President for Administration and Personnel at MIT, is serving as consultant on this project, and the Communications Office is handling the editorial and production work for the book. The new edition will be published in the fall of 1985.

Several items related to the Courses and Degree Programs catalogue are worthy of mention. The content and presentation of the departmental degree programs chapter were improved greatly in the 1984-85 edition, thanks to the help of Dr. David S. Wiley, Executive Officer of the Committee on Educational Policy (CEP), and Professor Arthur C. Smith, Chairman of the Faculty. Dr. Wiley suggested ways to more effectively present details of each curriculum and provided editorial guidance in the departmental descriptions. Professor Smith participated in and supported these efforts, which helped immeasurably in ensuring their acceptance in the departments.

Changes in this chapter, combined with some streamlining in other sections, resulted in a book which is, we think, more manageable and useful, in addition to being 48 pages shorter.

For the past several years, an ad hoc catalogue committee has met, as needed, to discuss ways to improve the catalogue. The CEP is responsible for overseeing the presentation of the academic program in Institute publications, and the Chairman of the Faculty saw the ad hoc committee as an effective way to discharge the details of that responsibility on behalf of the CEP.

In January, Professor Smith proposed that the committee be more formally established, and his motion was approved by the CEP. The Ad Hoc Catalogue Committee will include the following: Chairman of the Faculty (chair); Chair of the Committee on Curricula; Chair of the CGSP's Subcommittee on Graduate Subjects of Instruction; the Committee on Curricula's Executive Officer (Associate Registrar); CEP Executive Officer; Manager, Communications Office, CIS; and others as may be designated by the Chairman of the Faculty. The Committee has provided the Communications Office with the backing necessary to effect some important changes in the catalogue, and we appreciate their support.

As noted in last year's report, non-applicants who request the catalogue are asked to purchase it for $4. This procedure has been effective in curbing waste of the book, and we were able to cut the print run of the 1984-85 edition by 10,000 copies, which resulted in a significant dollar savings.

Another catalogue-related item which deserves mention is the retirement on June 30, 1985, of Dorothy Staknis, our primary contact in the Registrar's Catalogue Office. For more than 10 years, Dorothy has been the liaison with catalogue coordinators and the two faculty committees which approve subjects and degree requirements. She has been meticulous with the details that are so critical in a book of this kind, and has worked tirelessly to meet or better copy deadlines. We sincerely appreciate her commitment to a high quality product year after year, and wish her a happy and healthy retirement.

Our role as publications consultants within MIT has been growing steadily. This year, we have been
able to help on about 40 projects, providing editorial and/or production assistance to members of the community. This assistance eliminates some of the mystery and frustration that can be inherent in trying to produce a publication, and our advice can also help offices save money.

In closing, I want to thank my small but dedicated staff of Mark Wilson, Barbara Engel, and our student workers and interns for their hard work and enthusiasm throughout the year. Barbara will be leaving MIT in August to earn her Ph.D. in music theory, and her excellent skills and personality will be sorely missed. She has been an invaluable member of our team, and the office won't be the same without her!

JANET SNOVER

Office of 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 Admissions Office; the Corporation; the Committee on the Visual Arts; Resource Development; a variety of programs in the School of Architecture and Planning, the School of Engineering, and the Sloan School of Management; the Special Summer Programs; and a wide range of special events and conferences coordinated by the Information Center. As in the past, the office provided major design and production support for the communications program of the Alumni Association. Overall, the office undertook 272 graphic design and publishing projects in 1984-1985.

In 1984-1985 Design Services received the CASE Gold Medal Award (Betsy Hacker), and the Silver Award (Dietmar Winkler). Ralph Coburn lectured at the Montserrat School of Arts and served on a panel to evaluate classwork and teachers performance. An exhibition of posters by Casey and Coburn was on exhibit at the MIT Museum. Celia Wilson received an Award of Merit from the American Association of Museums.

Jacqueline Casey received the Award of Excellence from the Art Museum Association of America and the Award of Distinction from the American Association of Museums. Her posters were included in "American Graphic Design: Thirty Years of Design Imagery", (McGraw-Hill Book Company).

In June Ms. Casey's posters will be shown at the International Design Conference in Aspen; a worldwide exhibition (including MIT) "Images of Survival: The 40th Anniversary of the Bombing of Hiroshima," and the Colorado International Invitational Poster Exhibition. She served as an advisor on the Federal Graphics Improvement Evaluation for the National Endowment for the Arts in Washington; and was a visiting critic for senior projects at the Rhode Island School of Design. She was also a juror for CASE Annual Awards.

In the coming year, MIT (with Ms. Casey as sponsor) will host the First National Design Conference of the American Institute of Graphic Artists, to be held at here in September. The logistics for this conference are being handled by the Office of Special Events in the Information Center.

JACQUELINE S. CASEY

Information Center

The Information Center continues its mission of providing general information and services to the MIT community and to visitors; assisting the international faculty, staff, and visitors; and coordinating major Institute events, dedications, and conferences.

Public Relations and Information Services. The Center answered thousands of telephone and office inquiries from the public and MIT community (and acted as a clearinghouse for mail addressed generally to MIT); conducted tours for over 6,900 visitors to the MIT campus; arranged for 45 delegates and for official greetings from MIT to other institutions' inaugural ceremonies; continued to maintain the central Institute mailing lists and a five-year planning calendar; maintained records and published a Tech Talk supplement for over 60 faculty and presidential committees; and researched and prepared reports for the Faculty Nominations Committee.

During the past year the Information Center, with other offices, discussed plans for a redesign of the Institute map. This project is intended to be complementary to the design of the overall Institute design projects.
The guided tours, primarily for prospective students and their families, are a popular public relations function of the Center. The head guide Andrew J. Chess (Course 7, '86) continued the tradition of hiring and training MIT students to conduct tours of the Institute. Special thanks to Matthew Denesuk (Course 6-1, '87) and Suzanne G. Sobel (Course 7, '87) for their public relations services in the Center and for conducting the guided tours this past summer. The following is a listing of guided tours conducted during the past year:

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospective Students</td>
<td>3,003</td>
</tr>
<tr>
<td>International Visitors</td>
<td>695</td>
</tr>
<tr>
<td>General Visitors</td>
<td>3,242</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>6,940</td>
</tr>
</tbody>
</table>

Visitors on Special Tours   759
Visitors on General Tours   6,181
**TOTAL**                  6,940

Special Events and Conferences. The Special Events Office coordinated 12 on-campus conferences this year and assisted as well with the logistical arrangements for the Admission’s Office Campus Preview and Minority Spring Weekend in April. The office welcomed Lisa Bartolet in August as senior secretary. Planning continues for several major international conferences which will be held during the summer of 1985.

In addition to conference coordination, this office handled the arrangements for 88 on-campus recruitment presentations by companies visiting MIT in conjunction with the Office of Career Services and Preprofessional Advising.

The director continued to coordinate many special events, including the Killian Lectures, dedications, celebrations, and Commencement. This year, Commencement was the largest in the history of MIT: over 7,000 family members and friends watched 1,750 graduating students receive 1,927 degrees. Lee A. Iacocca, Chairman of the Board of Directors and Chief Executive Officer of Chrysler Corporation, was the guest speaker.

International Visitors. The International Visitors Office continued its usual activities, serving the needs of international visitors, faculty, and staff on campus, and was also involved in some special activities, events, and issues during 1984-85.

The high point of the year was a naturalization ceremony held on 16 November 1984 in Kresge Auditorium. A record number for New England, 653 men, women, and children were sworn in as American citizens. It was a thrilling moment for all involved. A large group of MIT staff and students assisted Immigration and Naturalization Service personnel that day and worked with them in preparing for the occasion.

The Committee on International Institution Commitments continued to play a strong role in focusing campus concerns about issues regarding international proposals. Several topics provoked lengthy debate. While most proposals were not controversial, some were. The Committee's advice to the administration helped to establish conditions for the acceptance of international contracts. One proposal, discussed for several months, was finally rejected.

The Simpson-Mazzoli immigration bill did not survive a Congressional conference committee in the fall of 1984. Yet clearly immigration reform has more momentum now than it has had for 20 years. There is need for, and it seems likely there will be, some major changes in US immigration requirements yet the issues are surrounded by controversy. We have continued to be involved in the process -- letting our legislators and other universities know of our immigration concerns. MIT also protested the announced closing by the Department of Labor of its Boston regional office which handles labor certifications. It has been learned recently that the Department of Labor Boston office will not close -- we hope our input contributed to the reversal of that decision.

Looking back, 1984-85 was an interesting and busy year in the office -- the problems became more complicated, there were many people to serve, and more issues to confront. We look forward to continuing to serve the international community at MIT and to having an impact on immigration policy issues and international concerns on campus.

Special thanks to the Information Center staff -- Kathleen Barrett, Lisa Bartolet, Sarah Clere, Donald Ferland, Gayle Fitzgerald, Virginia Lyons, Terri Priest, and Lillian Whelpley -- who continue
to meet the demands of a heavy work load willingly and with an awareness of the needs of the MIT community and of the visitors to our campus. Ginny Silverman, a hardworking and capable administrative assistant in the International Visitors Office, chose not to return from maternity leave. Her position was filled by Dora Waldin.

MARY L. MORRISSEY
When the year started the indicators pointed to an expanding economy, and a continuing boom in the commercial electronics industry. After Christmas there were signs of hesitation in Silicon Valley and on Route 128 and by the summer many firms in which our students would normally be greatly interested had either instituted hiring freezes or had had layoffs. But any anxiety we had during the spring that the change in the economy would hurt students' job prospects proved unfounded. The recruiters kept coming, students showed little concern, and few students came in at graduation to say that they had been unsuccessful in their job search after doing all the right things. There were more who said that they had just started looking. Perhaps we were the beneficiaries of a lag between the thunder and the rain, and it is next year that we will feel the effect.

The number of companies and government agencies who came recruiting totalled 431, not much short of 1982's record of 450. The corresponding figures in 1982-83 and 1983-84 were 405 and 407 respectively. A record 227 companies ordered our resume book (which contained the resumes of 1036 students at all degree levels and in all fields, another record). Eighty-eight companies made arrangements with the Office of Special Events to hold information meetings, compared with 76 in 1983-84, and 50 two years ago.

Students showed their nonchalance by having fewer interviews - 9012 - down from 9898 the year before, 10,043 in 1982-83, and 10,004 in 1981-82. But these are all high figures; during the 1970's the number of interviews seldom exceeded six thousand.

If the change in the economic climate was apparent anywhere it was in the level of salary offers, which in general rose very little. Offers to seniors in electrical and mechanical engineering were up less than 4 percent; offers to seniors in chemical engineering did not move up at all (with the result that chemical engineering dropped to second place, below electrical engineering, in the ranking of undergraduate majors by salary). The largest salary increases in engineering - up to 8 percent - were at the PhD level. The premium paid for a PhD degree in electrical engineering over a bachelor's, which was down to 1.4 five years ago, is back to 1.6 (where it stood in 1974).

One field on which the sun certainly shone last year was architecture. As many as half a dozen firms came recruiting - a rare event because most of the time architectural firms count on candidates coming to them - and salaries were up as much as 10 percent.

There is a danger in summarizing the year statistically in this way because our students should not be thought of as economic units, input to a national manpower pool. This is the language of government agencies assessing the nation's resources in science and engineering. It is the language of a recent National Academy report, Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future (1985). It is sometimes a language we fall into at MIT.

In our advising of students and alumni we are daily reminded how individual they are and how much it is their unique futures they have in mind, not how they can fit into someone else's classification. Although the large numbers choosing to major in engineering, and in electrical engineering in particular, have led to some worries about lack of diversity in the student body, the students we see have never seemed more independent or more interesting. Recruiters remark on these qualities. So do new members of our staff who come with degrees from other colleges.

If we are especially likely to make this observation at MIT, it seems as if much the same observation is being made at other engineering schools. The National Academy report just mentioned, which speaks in one breath of the educational system producing "the fodder of the technology development process", later makes the following interesting comment: "Professors and employers alike refer to the dramatically higher communication and social skills of engineering students...as compared to past stereotypes of the engineer...Today's engineering student (i.e., since the mid-1970's) tends increasingly to come from a middle-class, professional family background rather than the noncollege background that characterized many young engineers in the period after World War II. The predominance of such young people in engineering schools is now very strong. On balance, they have a richer educational and cultural background and are more confident, more assertive than engineering students of years past."
This is not the place to consider whether there really has been a change in the character of engineering students. It is difficult to get a handle on the indicators. What is certain, however, is that MIT engineering students do not see themselves as only engineers. Nor do undergraduates in other majors identify themselves only with their disciplines. They have many interests, not all of them strictly technical, which they want to express in their careers and they look for the way to do it which will suit them best.

A considerable number who have majored in a technical discipline find that their interest in technical work is secondary to their other interests. Many, with their major occupying most of their time and energy, have difficulty identifying the other things they might do for a living. During IAP the office sponsored a series of six talks by alumni and others on "Things You Can Do With A Technical Degree Besides Hands-on Technical Work." The talks were very well attended. Two in particular drew crowds of a hundred or so: one on investment banking by Mr. Lars Toomre, '82 (a mechanical engineering major now at Shearson Lehman/American Express), and one on management consulting by Mr. Jeffrey D. Sollender, '82 (a biology major now at Booz, Allen & Hamilton). We wish to record our thanks to them and to the other speakers, Mr. Arthur W. Maurer, Rochester Telephone (who spoke on technical operations management), Mr. Richard L. Farber, '76, Coopers & Lybrand (actuarial consulting), Mr. Lawrence R. Seidel, vice president, American Management Systems (management information systems consulting), and Mr. Rudolph Ganz, vice president, Travenol-Genentech (technical marketing).

Students declared their broad interests again in their response to a new bachelor's level training program at Citibank in international banking. Mr. John S. Reed, '61, Citibank's new chairman, who conceived the program, included MIT in a short list of colleges to whom the program announcement was sent. Students who threw their hat in the ring included seniors in science and engineering as well as in economics and management.

There is also, of course, the evidence of MIT's applicants to medical school and law school. MIT applicants to medical school last year totaled 114, up from 109 the year before and 101 in 1982-83. The increase runs counter to a slowing in the number of applicants in the country at large. The number of undergraduates applying rose to 81, compared with 70 in 1983-84. Thirty-six were engineering majors. We do not have all the returns but preliminary figures indicate that 88 percent of the undergraduate applicants were successful, and 80 percent of the total applicant group.

We know of 27 MIT applicants to law school, of whom 16 were undergraduates.

The truth is that among the many services MIT renders to society, one of the most important is the education of young men and women. To borrow from the 19th century Oxford scholar and educational reformer, Mark Pattison, the recipient of a bachelor's degree in science or engineering is first of all a person, not a young scientist or engineer. For many students, the undergraduate disciplines are the vehicles of a liberal education more than a professional preparation. The students we see are splendid expressions of that education.

ROBERT K. WEATHERALL
INTRODUCTION

The 1984-85 academic year proved to be an exceptionally challenging and productive one for the Office of the Dean for Student Affairs (ODSA). We played the leadership role in the development of two Institute-wide policies; conducted a major survey and several forums on the quality of student life; prepared a major report to the Office's Visiting Committee, which met during the year; integrated two new programs into our Office; and further strengthened our staff through staff replacements and the new program additions.

After considerable discussion involving faculty, staff, and students, we generated a policy statement on the showing of sexually explicit films on campus, which was approved by the Academic Council. We also established an Ad Hoc Committee composed of faculty, staff, and students to preview proposed sexually explicit films and to determine the conditions under which they could be shown on campus. The second Institute-wide policy developed was on the use of alcohol at Institute supported or approved events. The policy development on this issue was aided considerably by the leadership shown by the Dormitory and Interfraternity Councils. We were also especially pleased with the interest shown by the Faculty Committee on Student Affairs.

During the Spring of 1984, a quality of student life survey was distributed to approximately one fourth of the undergraduate student body. Last fall several forums were held soliciting views from various student groups on the survey findings as well as on their experiences at the Institute. The survey asked questions about academic achievement and performance, the social/interpersonal climate on campus, the residential environment, and student activities. Information from the questionnaire and the forums formed the basis of a report to the Visiting Committee on Student Affairs.

The Visiting Committee at its meeting of February 10-12, 1985 focused its attention on the quality of student life at the Institute and specifically on the support services provided through the Student Assistance Services section of the ODSA. The Committee heard from undergraduate and graduate students as well as from representatives of several student groups including women, minority, international, and gay students.

The size and intensity of the response to the quality of student life forum that focused on minority students were such that a second forum was held. These forums and an independent set of meetings - of the Associate Provost for Education and the Dean for Student Affairs with the staffs of the Office of Minority Education and of the Undergraduate Academic Support Office - led to the formation of a group that has been examining a number of issues related to minority students. This group of faculty and administrators from various parts of the Institute is currently reviewing the total range of services provided to minority undergraduate students from recruitment through graduation. Some improvements have already resulted and more recommendations for change are likely to be made in the future.

Another major highlight of the year was the hiring of several outstanding individuals as staff replacements and the addition of the excellent staff of the Independent Activities Period (IAP) and Wellesley-MIT Exchange Programs. Joining the ODSA this year as replacements for departing staff were Janice Cooper, Judy Dougts, and Barbara Fienman. Mary Enterline and Maryglen Vincens became ODSA staff members, following the decision by the Office of the Provost to add the IAP and the Wellesley-MIT Exchange Programs to the Undergraduate Academic Support Office. The addition of these individuals has made the ODSA staff the strongest it has been in the last five years.

Several changes that occurred this year within the Faculty Resident System are described in some detail in the report of the Residence and Campus Activities Section below. These changes included the retirements of Professor and Mrs. Nathan Cook as Housemasters in MacGregor and of Professor and Mrs. Robert Hulsizer from Ashdown. In addition, Professor Judith Kildow and her husband, Alfred, decided to leave as Housemasters of East Campus. We are extremely grateful to these faculty families for their years of dedicated service to students and we shall miss their wise counsel. We are especially fortunate to have Professor and Mrs. Robert Kennedy assume responsibility for MacGregor and to have Professor and Mrs. Vernon Ingram become Masters at Ashdown. The selection process for East Campus has not been completed at this writing.

The sectional reports that follow describe services the ODSA has continued to provide in response to several student initiatives as well as through a variety of programs and activities.
Events this year have underscored the continuing need to improve communications with students and to
double our efforts to increase faculty contact with students outside of the classroom. Several new
initiatives to increase our interactions with students are being planned. We expect the change in
reporting structure of the ODSA to the Office of the Provost to increase our contact with faculty and to
result in their greater involvement with students.

We are generally pleased with the year's developments and are deeply appreciative of the support that
many faculty, students, and staff have provided to our efforts throughout the year.

SHIRLEY M. MCBAY

UNDERGRADUATE ACADEMIC SUPPORT

The Undergraduate Academic Support (UAS) Office coordinates the freshman and undesignated sophomore
advising programs; the orientation programs for all new undergraduates; and serves as an academic
information center for students, individual faculty members, and departments. The office also serves as
the administrative support structure for the Faculty Committee on Academic Performance, the January
Independent Activities Period, and the Wellesley-MIT Exchange Program. The major UAS programs are
described below.

FRESHMAN ADVISING PROGRAM

The primary counseling of freshmen during 1984-85 was carried out by 236 advisors (130 faculty, 15
lecturers/instructors, 18 research staff members, 18 graduate students, and 55 members of the
administrative staff). These advisors were supported by nearly 200 undergraduates who served as
"associate advisors."

Eighteen freshmen withdrew for a variety of personal reasons during the academic year. Thirteen
additional freshmen were required to withdraw for at least one term because of unsatisfactory academic
performance. The table below summarizes for the past four years actions by the Committee on Academic
Performance regarding unsatisfactory academic performance as well as the number of the more informal
letters from our office 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>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>
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<tr>
<td>1982-83</td>
<td>17</td>
<td>109</td>
<td>73</td>
<td>199</td>
</tr>
<tr>
<td>1981-82</td>
<td>8</td>
<td>93</td>
<td>98</td>
<td>199</td>
</tr>
</tbody>
</table>

The low number of academic actions relative to past years seems to bear out the observations by a number
of faculty that this has been a particularly diligent and hard-working freshman class.

UNDESIGNATED SOPHOMORE ADVISING PROGRAM

Thirty-one faculty and staff advisors counseled the 69 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 30. The respective student figures for 1983-84 were 83 and 28 for the fall and spring terms
respectively.

SUPERVISION AND COORDINATION OF RESIDENCE/orIENTATION (R/O)

Our fall term residence/orientation program, designed to welcome all new undergraduates, is produced
almost entirely by students under the leadership of an R/O coordinator who this year was Kathryn
Chamberlain, Class of 1985. Highlights of this year's R/O activities included a continuation of the
successful "pre-picnic" discussion groups initiated last year, the introduction of a luncheon for the
parents on parents' weekend, and an unusually high number of upperclass volunteers.

Andrew Eisenmann of the Residence and Campus Activities Section has assumed primary responsibility for
supervision of the R/O Coordinator while other members of the ODSA have responsibility for overseeing
students' efforts in specific aspects of R/O Week.
ADMINISTRATIVE SUPPORT TO THE COMMITTEE ON ACADEMIC PERFORMANCE (CAP)

The CAP was chaired this year by Professor Vernon Ingram. During the year, the Committee handled approximately 425 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 96 Required Withdrawals (approximately 2 per cent of the undergraduates) and 364 Warnings (approximately 9 per cent) were voted for the academic year. These figures were distributed by class as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Required Withdrawals</th>
<th>CAP Warnings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of 1985</td>
<td>22</td>
<td>75</td>
</tr>
<tr>
<td>Class of 1986</td>
<td>13</td>
<td>85</td>
</tr>
<tr>
<td>Class of 1987</td>
<td>48</td>
<td>126</td>
</tr>
<tr>
<td>Class of 1988</td>
<td>13</td>
<td>79</td>
</tr>
</tbody>
</table>

The CAP office also operates as an information center for academically-related policies and procedures. A highlight of the year was the publication of the revised CAP Guide for Undergraduates and Faculty Advisors.

THE UNDERGRADUATE SEMINAR PROGRAM

There was a decrease over last year in the number of offerings in the Undergraduate Seminar Program (from 52 to 49 in the fall semester and from 38 to 37 in the spring). The large number of students who choose to participate in the program continues to underscore the importance of the seminars as a complement to the regular curriculum. Approximately 1,170 students (of whom 694 were freshmen) participated in seminars this year, continuing the upward trend of enrollment in seminars on the part of upperclass undergraduate students.

This year, Associate Provost Frank Perkins served as interim chairman of the Program.

INDEPENDENT ACTIVITIES PERIOD (IAP)

In July of last year UAS welcomed the IAP and Wellesley-MIT Exchange Programs, which had previously reported to the Office of the Provost.

The 1984-85 academic year was an eventful one for the Independent Activities Period. Not only did MIT's January program celebrate its fifteenth year, but it underwent a major change with the elimination of the First IAP Guide and the issuance of only one guide. In observation of IAP's birthday, and as a means of publicizing the switch to one guide, the IAP Policy and Administrative Committees declared October to be "IAP Planning Month" and set up displays in Lobby 7 featuring activities from the previous 14 IAP's.

As a result of this increased visibility for IAP, 620 activities were offered in IAP '85, the second highest number ever. As always, there was a rich variety of academic and nonacademic subjects.

At the end of IAP, a questionnaire was sent to all faculty members to find out how they spent their time during IAP and how they rate the program. More than 40 per cent of the faculty responded to the questionnaire. Over 80 per cent of the respondents said that they were at MIT for 75 per cent of IAP, and on a scale of one (poor) to five (excellent) they gave IAP an average rating of about four. In the IAP Policy Committee's four-year report to the faculty, Chairman Shaoul Ezekiel summarized the results of the faculty survey, earlier surveys of the student body, and data collected annually on the guide activities. While the Committee did not recommend major changes in the structure and policies of IAP, it did remind the faculty that they are responsible for the educational content of IAP and should be more involved with undergraduates during this period. Specifically, the Committee recommended that:

1) faculty and departments become more involved in helping undergraduates plan their IAP activities;
2) efforts be increased to inform students about the valuable experiences and skills that can be attained through leading activities; and
3) IAP be included in the initiative to improve undergraduate education announced by Provost-designate John Deutch.

WELLESLEY-MIT EXCHANGE

For the sixteenth 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 students cross-registering was comparable to previous years. In the fall semester 105 MIT students registered for 149 Wellesley subjects while 155 Wellesley students took 222 MIT subjects. As in the past, the number of cross-registrants increased in the spring: 158 MIT students enrolled in 186 Wellesley subjects and 198 Wellesley students in 267 MIT subjects. Among the cross-registrants was an MIT biology major, Mary Petrofsky, who earned certification as a secondary school teacher through the Education Department at Wellesley.

In addition to cross-registration, the Exchange continued to administer a small residence exchange program involving approximately 15 students from each school.

While students did most of the traveling between the two schools, two members of the Wellesley Religion Department commuted to MIT. During the first semester Professor Roger Johnson taught Religion 107, Crises of Belief in Modern Religion, at MIT, and in the spring Assistant Professor Holly Reynolds offered Religion 108, Introduction to Asian Religions.

ACADEMIC SUPPORT AND INFORMATION CENTER

Activities in this area are designed to encourage a strong undergraduate support system for both students and faculty, with the goal of improving the advising and teaching programs for undergraduates. Examples of expanded or new efforts include the following:

1) Co-sponsoring, with the Office of the Provost, an orientation and workshop for all new teaching assistants in the Fall of 1984, followed by a second program during IAP.

2) Preparation of some general guidelines for addressing issues relating to academic honesty for possible use by departments and individual faculty.

3) A Peer Advising Fair, at the end of the Spring term, to assist freshmen with subject selection and general advice about their future departments.

CAREER AND COURSE ORIENTATION

Initial figures regarding course selection for the Class of 1988 indicate a continuing downward trend in enrollments in the Department of Electrical Engineering and Computer Science. We continue to participate in a number of efforts designed to improve information available to students about opportunities open to them. These include the publication of departmental "Roadmaps" encouraging advisors to work actively with their freshmen in discussing course options.

We work closely with departments in the planning and coordination of spring term departmental "open houses," and the UAS "Reading Room" is continuing to improve its stock of resource information about departments and disciplines.

STAFF

Staff within the UAS served as ex officio members of the Committee on Curricula, the Committee on Undergraduate Admissions and Financial Aid, and the Committee on Academic Performance. We held membership on the Wellesley/MIT Exchange Committee, the IAP Administrative Committee, the Activities Development Board, the Committee on Privacy, and the Pre-Law Advisory Council.

Margaret Richardson has assumed responsibility for the coordination of information about all Institute awards and prizes and is responsible for the entire process surrounding the Spring Awards Convocation.

As we assumed the additional administrative functions of the January IAP and the Wellesley-MIT Exchange, we welcomed the staff of those programs — Mary Enterline, who is manager of both programs, and Maryglenn Vincens, Editor of the IAP Guide. During this first year, both have made general and creative contributions to other programs in our office.

Finally, we were pleased to welcome back Margaret Richardson after a leave of absence following the birth of her daughter in July, 1984.

HOLLIDAY C. HEINE
BARBARA S. CHUCK
MARY Z. ENTERLINE
JEFFREY A. MELDMAN
STEPHEN M. PATTERSON
MARGARET S. RICHARDSON
MARYGLENN VINCENS
This year the Visiting Committee for Student Affairs focused on the Student Assistance Services Section (SAS) of the Office. We in turn used the Committee's visit as an opportunity to explore in depth the quality of student life at MIT. In preparation for the visit, we distributed a Quality of Student Life Survey and held a series of forums to gain additional information from students and to validate the information gained from the Survey.

Significant also for Student Assistance Services during the past year has been the completion of our team. Janice Cooper, formerly of Brandeis University, joined the office in July and immediately began to pull together programs aimed at improving support services for minority students. In the spring, Lynn Roberson replaced Sara Mae Berman as Staff Assistant for Women Students. Ms. Roberson came from within the Institute and brought both enthusiasm and a knowledge of this environment. At the same time, Karen Zuffante replaced Kathy Lutfi as Administrative Assistant working with International Students. Ms. Zuffante came from Georgetown University and brought a familiarity with the needs of international students. These individuals are all professionals and have made the office stronger than at any time in the past three years.

Student Assistance Services remains fundamentally a resource for personal, academic, and other types of counseling. Students made 3986 appointments during the year, including 1164 visits by international students. This number does not take into account the quick drop-ins missed from regular tally sheets.

As we have become more committed to making the environment of MIT all that it can be for a multifaceted community, we have increased the responsibilities of the ODSA in general and of SAS in particular. Greater attention to constituencies becomes important and efforts to gain support from varied groups are significant building blocks in creating the kind of community we seek.

International Students

During 1984, there were 2135 international students from 96 countries enrolled at MIT, constituting 22 percent of our student body. Of that number, 337 were women and 567 were undergraduates. These figures represent a slight increase over the previous year.

The Foreign Scholarship Committee this year reviewed a larger number (29) of applicants for study abroad than in recent years. Nine students were placed in foreign universities under the auspices of the Fulbright-Hayes program, the German Academic Exchange Service Awards, and the Department of Education. There were no recipients of Churchill, Rhodes, or Marshall awards this year.

We were pleased with the Institute's recognition of Gene Chamberlain's contributions over the years to the MIT community through his receiving the Billard Award at the Awards Convocation in May. Dean Chamberlain continues to provide leadership in a number of humanitarian endeavors in addition to his role in providing services to international students.

Special Groups

The meeting of our Visiting Committee in February provided an opportunity for many women in the community to again vocalize their concerns about such issues as pornography, sexual harassment, and isolation. Our office will continue our efforts to help resolve these issues and to establish community standards in these areas.

On a more positive note, a very successful Women's Culture Program in May attracted a large audience of men and women from across the Institute. This event gave additional visibility to the organized presence of women in our midst. The Cheney Room Papers, edited by Lynn Roberson, have continued to be a vital link in the communication chain within the women's community.

Linda Vaughan was promoted in January from Assistant Dean to Associate Dean for Student Affairs in recognition of her overall contributions to the Institute. In particular, Dean Vaughan's role in working with women students at MIT was given increased prominence by this well-deserved promotion.

Nightline continues as a peer support group, using the telephone to dispense information, advice, and care. In April, Nightline sponsored a student-run forum on depression that was well attended and resulted in plans for two more forums for the coming year. This program was a direct result of the information gathered from the Quality of Student Life Survey, which indicated that a large percentage of students turn to peers for emotional support in times of depression and related difficulties. The training of peers seemed a natural response and the linkage of Nightline and SAS was an appropriate way to implement it. Nightline also serves as an important model for what students who care about their environment can do to make it better. This organization remains a prime example of a program that works to make the quality of life here at MIT better for everyone. Strong leadership was provided this year by Angela Dispensieri, Karin Nilsson, and Martin St. George.
For several years there has been a growing concern about alcohol and related problems on college campuses in general and at MIT in particular. Beginning in 1983, efforts were started under the leadership of Leo Osgood to reshape our approach to alcohol use. The ODSA has played an important role in subsequent events and recently helped formulate a new Alcohol Policy that has been adopted by the Academic Council. This policy caps an effort that has drawn on a wide segment of the community and marks an extremely important step in making MIT a more responsible institution.

The 1984-85 academic year was a very busy one for the Committee on Discipline. In comparison to last year, the number of cases doubled (from 4 to 8) and the complexity and nature of the cases changed dramatically. Dean Osgood played an important role as ODSA's liaison to this Faculty Committee.

Our efforts to reach out to the minority community have been strengthened by the work of Janice Cooper. We recognized when she joined us that we had ground to make up and credibility to reestablish. Dean Cooper quickly helped with these needed tasks by working with students to plan one of the most successful minority orientation programs in recent memory. That effort was enhanced by the publication of a Minority Support Services Guide as a supplement to other R/O publications. Two Quality of Student Life meetings with minority students provided considerable insight into the often less than positive experiences of some minority students here as did the panel discussions during the meeting of the Visiting Committee. Much remains to be done in this regard and we are hopeful that by working more closely with the Office of Minority Education and with students we can begin to make some improvements.

The luncheon in honor of all graduating minority students sponsored by the ODSA and the Graduate School Office is always a grand way to end the year. This occasion provides an opportunity for graduates to introduce their parents and to comment on their experiences at MIT.

Overall, the year has been a good one and we are positioned as a section to make important contributions in the year ahead. Two issues will be of particular concern: (1) the development of new models for effectively improving the human relations climate on campus and (2) the strengthening of our ability to measure and meet the needs of our growing international community. These are not new concerns but they remain vital to our educational enterprise.

ROBERT M. RANDOLPH
EUGENE R. CHAMBERLAIN
JANICE R. COOPER
LEO OSGOOD
LYNN A. ROBERSON
LINDA J. VAUGHAN

RESIDENCE AND CAMPUS ACTIVITIES

Institute Houses

The Institute's houses remained high in popularity again this year, during both the academic year and the summer. Return rates for upperclassmen combined with the freshman class size of 1059 resulted in 119 crowded rooms in the fall and a substantial waiting list. The high number of residents staying on for the summer and the large number of summer conferences, combined with extensive physical renovations, have resulted in a major shortage of Institute housing space for the second straight summer.

The continuing shortage of graduate student housing remains serious as is shown by the lengthening waiting lists for on campus housing. The cost of living off campus is increasing and the availability of apartments is steadily decreasing. Furthermore, more faculty are beginning to express concern about the effect of the housing shortage on graduate student admissions.

Faculty and Graduate Resident Program

Three Faculty Residents announced their plans to leave the residence system at the end of this academic year. Nate and Collie Cook, MacGregor House's first and only Senior Faculty Residents, will retire after 15 years; Bob and Carol Hulsizer will leave after 11 years in Ashdown House; and Judy and Alfred Kildow will depart after three years in East Campus. The residents of MacGregor House and of Ashdown House sponsored parties at which rooms were dedicated in honor of the Cooks and the Hulsizers in recognition of their many years of devoted service to the residence program.

Professor Robert S. Kennedy of the Department of Electrical Engineering and Computer Science and Mrs. Kennedy have been appointed Faculty Residents of MacGregor House. Professor Vernon M. Ingram of the Biology Department and Mrs. Ingram have assumed the role of Faculty Residents of Ashdown House.
We are experiencing difficulty in filling the Faculty Resident vacancy in East Campus even though more than 60 tenured professors have been contacted thus far. The most frequent reason given by those declining to be considered was the pace and pressure on them as faculty members and their resulting inability to take on more responsibility, despite their personal interest in being more involved with undergraduates.

Our efforts to fill the newly created Junior Faculty Resident position in East Campus have been much more fruitful and we expect to make an appointment shortly. This position was added to assist the Senior Faculty Resident in carrying out the responsibilities in our largest House.

In response to a request by the residents of McCormick Hall, a new position entitled Resident Faculty Fellow has been created to replace one of the Graduate Resident positions there. Professor Sally Deutsch and her husband, Kimball Smith, have been appointed to this position.

We were very pleased with the appointment of Professor Jay Keyser to the position of Associate Provost and the announcement that the Office of the Dean for Student Affairs would be now reporting to Associate Provost Keyser. Jay and his wife Margaret have been Faculty Residents in Senior House for the past four years.

Dining Program

Following surveys of their respective residents, Baker House voted to remain a commons house with several modifications while MacGregor and McCormick Halls opted for an a la carte service, which was instituted during the Spring term. The Dining Advisory Board is expected to examine the current point and cost per meal system and to take a look at restructuring the compulsory commons plans in response to concerns expressed by residents.

Fraternities and Independent Living Groups

Approval was given last spring to reestablish a full term Advisor to Fraternities, but we were unable to successfully fill the position until January of this year, and the individual selected was not able to begin work until this June. This unfortunate circumstance resulted in a significant reduction in our services to fraternities this year.

A great deal of time was devoted over the year to charges of sexual harassment, harassment of gay students and homosexual acquaintance rape, as well as to alcohol abuse. The topic of "dry rush," the 21-year-old drinking age, and legal liability were discussed repeatedly with undergraduates and alumni corporation officers. With the assistance of the Dormitory Council and the Interfraternity Conference, the Dean's Office developed a policy statement on the use of alcohol, especially during Residence/Orientation week.

Two issues that will have important implications for the fraternity system over the next few years are the renovation of the Harvard Bridge and the integration of Project Athena into the residence system. We will work with students and others to minimize any disruptive impact.

Campus Activities

The 1984-85 year focused on implementing the previous year's goals and improving relations with more than 150 student activity groups. The initial phase of the two-year transition project is underway. Steve Immerman, former Assistant Dean for Student Affairs, has been hired as the Director of Operations for the West Plaza Complex. The project's goal is a self-sufficient campus activities complex. Development of the commercial space on the first two floors of the Student Center is being studied and steps are being taken to centralize the scheduling functions of two of the offices in that building. Several planning sessions and retreats were conducted with student government leaders, the Student Center Committee, and the Finance Board. A number of initiatives were identified for the fall that are designed to improve student government and to increase leadership development opportunities for our students.

The Jerome B. Wiesner Art Gallery in the Student Center celebrated its first anniversary with a special exhibit and reception. Highlights during the year included ten shows from a wide range of programs and activities.

The issue of showing sexually explicit films remained a major topic during the first semester of the year. The ad hoc screening committee appointed by the Dean's Office was able to implement the policy developed on sexually explicit films. This success should lessen the tension surrounding the showing of these films and hopefully lead to some long-term solutions.
Graduate Student Council (GSC)

The GSC was particularly active this year and quite successful in keeping issues facing graduate students before the Institute community. Much of the Council's success can be attributed to this year's President, Rene LeClaire, whose quiet statesmanship and leadership style set a tone for accomplishment.

One specific action that may have a lasting effect on graduate student life at MIT was the development of a set of Graduate Student Rights and Responsibilities (GRR). This document spells out guidelines for relationships between faculty and students and offers standardized administrative procedures for Teaching and Research Assistants. It is currently under consideration by a joint committee of the Committee on Graduate School Policy and members of the GSC and is slated for public discussion during the fall term.

Other GSC accomplishments include the publication of the Graduate Student News and the sponsoring of several social events. Both sets of activities were successful in improving communication among graduate students.

Talbot House

Talbot House has continued to enjoy popularity with a variety of groups from the MIT community. During the 1984-85 academic year, 110 different groups submitted applications and 50 groups, comprised of 1,104 individuals, visited the Institute's retreat house in Vermont. The house was occupied 140 nights out of the year and 4,929 meals were served. During the year, Talbot House was occupied 35 weekends and 15 groups made visits during the week.

The house continued to attract a variety of groups within the MIT community. Twenty three academic groups, 10 living groups, 9 associations or clubs, 3 alumni groups, and 5 faculty/staff groups were represented. IAP was the most active month with 9 different groups taking advantage of the winter sports season.

These groups were accommodated despite the fact that Talbot House was closed for almost four months (from mid-June until early October) for renovations. A new kitchen and first floor plan now permit more efficient cooking, heating, and fire safety in the 100-year-old farm house. Additional renovations, which are to begin in June, will add needed bathroom facilities, bring the stairways and upstairs access ways into agreement with fire codes, and provide improved cleaning and storage facilities. In spite of these renovations, the house is expected to reopen before Labor Day.

Athena Deployment

A major planning effort is underway to prepare living groups to receive Project Athena work stations. Initial deployment is expected to begin in late Spring, 1986. Each living group is expected to submit plans on location, security, quantity, and configuration. Unanswered questions at this time include who will fund the renovations necessary to implement these plans and how the independent living groups in Boston, Brookline, and Cambridge will be added to the Athena network.

Quality of Student Life Survey

The data collected during the Spring Term of 1984 from the Quality of Student Life (QSL) survey were analyzed and the results were reported to the community during this academic year. The 20-page survey booklet, containing 86 questions measuring 290 variables in four major areas, was mailed to 1,000 undergraduates in February, 1984. The survey was an effort to gather student opinion on aspects of the physical and social environment at the Institute that might significantly affect student performance and experience at MIT.

Assistant Dean Peter Brown developed the analysis and presented the findings to over 20 Institute committees, offices, and student groups. The findings were also the focus of attention at several forums and formed the basis for discussion at the meeting of the ODSA Visiting Committee.

Discipline and Harassment Cases

A report on discipline cases involving students from living groups that were adjudicated by staff in the Residence and Campus Activities Section is available in the ODSA. In summary, four students were suspended from their residences, one was suspended from the housing system, seven were declared persona non grata, fourteen were placed on Dean's Office Disciplinary Probation, four were given Dean's Office Disciplinary Warnings, nine were required to pay financial restitution for damages done, three were issued restraining orders, three were referred to the Cambridge Fire Department for further action, and six were required either to write a letter of apology or to develop an educational project related to their discipline charge. One fraternity was placed on disciplinary probation. A number of cases were handled through verbal disciplinary warnings and referrals to counseling. Offenses included harassment, breaking and entering, alcohol and drug use/abuse, malicious destruction of property, setting of fires,
and unacceptable behavior or hacking.

Staff Changes

Ann Braden was promoted to Staff Assistant for Residence Programs following the departure of Kathleen Haskell.

New staff appointments included Judith Douglis as Executive Officer, Mark Ertel as Advisor to Fraternities, and Barbara Fienman as Campus Activities Advisor.

ROBERT A. SHERWOOD
PETER H. BROWN
JUDITH M. DOUGLIS
ANDREW M. EISENMAN
BARBARA M. FIENMAN
KATHLEEN HASKELL
RETA M. LEE

ATTACHMENTS TO THE ODSA REPORT:

Policy on Sexually Explicit Films
Policy on the Use of Alcohol
Fall, 1984 Institute Undergraduate House Count
Fall, 1984 Regular Graduate Student Residential Distribution
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

POLICY STATEMENT ON SEXUALLY EXPLICIT FILMS

The Institute wishes to protect the expression of ideas even when these ideas might be unpopular and offensive; it will therefore not categorically deny space to an MIT-recognized group for the showing of sexually explicit or pornographic* films. The Institute will, however, make decisions regarding the time, circumstances, and location of the showing of such films without compromising the protection of expression.

In this connection, the Dean for Student Affairs will appoint an ad hoc committee (of approximately 12 individuals) including Lecture Series Committee (LSC) and non-LSC student members, faculty, and staff to develop or adopt criteria for those sexually explicit films that may be shown on campus. This Committee will also be asked to review x-rated or unrated sexually explicit films, prior to public showing, to determine whether the films meet the criteria established by the Committee. Films brought to the Committee are expected already to have been pre-screened by the LSC (or by any other group proposing to show such films) using the Committee's criteria as a guide. No x-rated or unrated sexually explicit film should be shown without prior review by this Committee. If the Committee finds that a film meets the established criteria, then this film may be shown on the same basis as any other film on campus.

If the LSC, or any other group, decides to show a film which does not meet the criteria, the following conditions will apply:

- The film may not be shown on Registration Day of either the fall or the spring term, nor during the R/O period at the beginning of the fall term. The showing of such films during or at the end of the freshman orientation period is not an appropriate introduction to this community for incoming students, particularly freshmen. Furthermore, showing such films on Registration Day of either term serves to establish an undesirable tradition of such showings.

*This policy assumes the definition of pornography as used in an article by Helen E. Longino entitled "Pornography, Oppression, and Freedom: A Closer Look" and appearing in Take Back The Night: Women on Pornography, edited by Laura Lederer, Bantam Books, 1980. Pornography is defined there as "verbal or pictorial explicit representations of sexual behavior that, in the words of the Commission on Obscenity and Pornography, have as a distinguishing characteristic 'the degrading and demeaning portrayal of the role and status of the human female [or male]...as a mere sexual object to be exploited and manipulated sexually'".
Such a film may not be shown in Kresge Auditorium. In the past, several unpleasant incidents following these showings have been reported. Kresge Auditorium, where these films were usually shown, is in close proximity to McCormick and Green Halls, the women's dormitories on campus. In order to avoid possible disruptions and unpleasant encounters for students, especially women students, as they move within their normal environment, Kresge will no longer be used for such films.

Sufficient prior notice must be given of the intent to show such a film in order to allow others adequate time to plan, schedule, and advertise an alternative and concurrent program. The LSC or any other group planning to show sexually explicit films must notify the ODSA of this intent at least six weeks prior to the proposed showing date.

The following additional conditions, while stated specifically in terms of sexually explicit films, are appropriate for the showing of all films:

The LSC or any other group showing such a film is responsible for the provision of arrangements that will assure suitable conduct during the showing of the film. There have been several reported incidents of unbecoming behavior by members of the viewing audience during the showing of sexually explicit films. The group showing such a film may wish to consider prior warning to individuals or groups known to behave in an unbecoming manner at such screenings. A sponsoring group can and should seek assistance from the Campus Police in maintaining order.

The LSC or any other group showing a sexually explicit film will be expected to show good taste in the advertising of any such films.

Violations by the LSC or any other group of any of these conditions can result in a hearing by the ODSA. A range of sanctions are available, including the recommendation that the group be denied the use of MIT space in the future.

Continued discussion and cooperation on the part of students, student organizations, faculty, and staff are essential to the successful resolution of concerns around this issue as are continued efforts to identify acceptable films. This policy will be reviewed following a trial period of at least one year and any necessary revisions will be made at that time.

Office of the Dean for Student Affairs
August 14, 1984
General Policy

MIT supports the observance of all laws and regulations governing the sale, purchase, and serving of alcoholic beverages by all members of its community and expects that these laws will be adhered to at all events associated with the Institute. This includes activities on the MIT campus, in MIT-approved independent living groups, and at off-campus functions sponsored or supported by MIT or any of its affiliated groups. A reference guide to existing state laws is available from the Office of the Dean for Student Affairs.

The Institute strongly encourages all faculty, staff, and students to become familiar with these laws and to consider the associated penalties and other potential risks that can result from violations.

Included in these laws are those that govern driving under the influence of alcohol, the purchase of alcohol by and for persons under the legal drinking age, and the serving of alcohol to persons who are either under age or intoxicated. It should be noted that the drinking age in Massachusetts will be raised to 21 as of June 1, 1985, and will apply to all individuals who have not turned 20 before that date.

The Institute does not intend through its guidelines or policies to restrict the responsible use of alcohol by members of the MIT community who are at or above the Massachusetts legal drinking age. However, efforts to observe existing laws and regulations in an environment in which the majority of the undergraduate student body will no longer be of drinking age will almost certainly impose some constraints upon those who are of age.

Residence/Orientation (R/O) Policy

The increase in the drinking age to 21 by the State of Massachusetts virtually guarantees that all freshmen entering MIT will be under age. This situation places a special responsibility upon all members of the Institute community planning activities for freshmen to insure that alcohol is not made available to them on such occasions. Of special concern are activities held during Residence/Orientation, an official part of the MIT calendar of events, designed to orient new students to the MIT environment and to assist them in the selection of a living group.

Given the purpose of the Residence/Orientation period and the under age status of the majority of freshmen, a special policy on the use and availability of alcohol is needed during the initial days of R/O when activities are primarily focused on freshmen.

In view of the historic emphasis on self-governance within the Institute's residential system, it is important to have such a policy developed and enforced by students. The Institute has therefore decided to adopt the following policy on R/O that is based upon separate policies developed by the Dormitory Council and the Interfraternity Conference respectively:

Rush will be dry from Friday afternoon to Monday evening with the exception of Saturday and Sunday from
6:00 p.m. to 1:00 a.m. beginning with R/O, 1985. A dry rush is defined as the absence of alcohol at events in common areas during the period when freshmen are being recruited for dormitories, fraternities, and other independent living groups.

Living groups may serve alcohol at the times noted above in compliance with all current city and campus policies provided they meet the following guidelines:

(1) The living group planning the event must send at least four representatives to an Alcohol Education Session (AES)

(2) At the AES all Rush workers will be presented a pamphlet explaining all guidelines along with a statement which must be signed that indicates agreement to abide by and enforce all of the guidelines given.

The first AES will be run jointly by the Undergraduate Association Social Council and the Campus Activities Office, with representatives from the Interfraternity Conference acting in an advisory capacity, on the Wednesday preceding the Freshman Picnic. At this session, potential liabilities will be explained and the following guidelines which govern all events where alcohol is to be served will be reviewed:

(1) All persons will be required to present a positive proof of age at all entrances to the event.
(2) All persons of drinking age expressing a desire to drink must be given a stamp or a wristband as proof of their status.
(3) Alcohol can be served or made available only to persons who have been stamped or given wristbands.
(4) There must be both non-alcoholic beverages and food readily available.
(5) All alcohol must be served by official Rush workers.
(6) A server must not serve more than one drink to any individual at any particular time.
(7) Alcohol must not be served to any person who is intoxicated.
(8) Any violation of these provisions will be dealt with by the appropriate judicial body.

Enforcement

The Institute recognizes it cannot guarantee that this policy or the alcohol-related laws will be honored by everyone. It must therefore rely upon the good judgment of students, student groups, faculty, staff, and other members of the Institute community to observe the relevant policies and laws. Those who choose to violate them must be prepared to accept total responsibility for their individual or collective actions and should understand that possible outcomes include disciplinary action, loss of rush privileges, personal liability, fines, and/or imprisonment.

Review of Policy

The Residence/Orientation section of this policy will be reviewed following R/O, 1985. Other sections will be reviewed as necessary.
## INSTITUTE UNDERGRADUATE HOUSE COUNT

### Fall 1984

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<tr>
<th>HOUSE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Other</th>
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<th>Total</th>
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<td>417</td>
<td>208</td>
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## GRADUATE RESIDENTIAL DISTRIBUTION

### Fall Term 1984

#### Regular Graduate Students

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<th>MIT HOUSING</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
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<tr>
<td>Green</td>
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<td>Tang</td>
<td>345</td>
<td>59</td>
<td>404</td>
</tr>
<tr>
<td>Graduate Residents (Single)</td>
<td>22</td>
<td>16</td>
<td>38</td>
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<tr>
<td><strong>Total Single Graduates -- On Campus</strong></td>
<td><strong>691 (18.8%)</strong></td>
<td><strong>187 (20.2%)</strong></td>
<td><strong>878 (19.1%)</strong></td>
</tr>
<tr>
<td>Eastgate*</td>
<td>185</td>
<td>30</td>
<td>215</td>
</tr>
<tr>
<td>Westgate*</td>
<td>195</td>
<td>19</td>
<td>214</td>
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<tr>
<td>Graduate Residents (Married)*</td>
<td>25</td>
<td>8</td>
<td>33</td>
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<tr>
<td><strong>Total Married Graduates -- On Campus</strong></td>
<td><strong>405 (11.0%)</strong></td>
<td><strong>57 (6.1%)</strong></td>
<td><strong>462 (10.0%)</strong></td>
</tr>
<tr>
<td><strong>Total Graduates -- On Campus</strong></td>
<td><strong>1096 (29.8%)</strong></td>
<td><strong>244 (26.3%)</strong></td>
<td><strong>1340 (29.1%)</strong></td>
</tr>
<tr>
<td><strong>OFF CAMPUS</strong></td>
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<td>2580 (70.2%)</td>
<td>683 (73.7%)</td>
<td>3263 (70.9%)</td>
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<td><strong>TOTAL REGULAR GRADUATES</strong></td>
<td><strong>3676 (100%)</strong></td>
<td><strong>927 (100%)</strong></td>
<td><strong>4603 (100%)</strong></td>
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*There are fifteen couples in Eastgate where both members are students, eight in Westgate, and five Graduate Resident couples where both members are students.*
With enthusiasm and a great deal of satisfaction about the past year this is to submit my fifth annual report of our expanding and improving athletic and recreational programs for the MIT Community.

A concise statistical review of our wide-ranging activities has been compiled and submitted separately for forwarding to the Institute Archives.

This report will highlight the achievements and student outreach of our programs with emphasis on the continuing extraordinary leadership provided by our teachers, coaches and administrators for the benefit and enhancements of the MIT Community human environment.

One highlight of the past year is the consolidation and strengthening of two of our most popular, visible and successful programs - volleyball and crew. Men's Volleyball will move from club to intercollegiate status next year and both men's and women's intercollegiate volleyball will have the coaching and leadership of first year full-time women's and men's coach Karyn Altman. In 1983-84 as a part-time coach of men's volleyball Karyn was selected Division III National Coach of the Year for leading the MIT Women's Volleyball Team to a final four NCAA ranking. This past year Karyn and the women's team were even more successful finishing second in the NCAA tournament - the highest NCAA level ever achieved by any MIT team. The team and Karyn were recently honored with the MAIAW Achievement Award presented for the most outstanding achievement in the current year in women's athletics in Massachusetts.

The success of our women's volleyball program and the overall vitality and richness of our many programs for women members of the MIT Community are direct results of the sustained high quality vision and leadership of Assistant Director of Athletics, Professor Jane Betts. Appropriately she was also honored at the annual meeting of the MAIAW (Massachusetts Association of Intercollegiate Athletics for Women) with the MAIAW Merit Award for her continued service and leadership in women's athletics in Massachusetts.

The women's and men's intercollegiate crew program at MIT will be under the leadership of newly appointed Director of Crew, Professor Bruce Beall. Professor Beall is currently the Head Coach of Lightweight Crew at Harvard and National Coach of the U.S. Lightweight Team. A former Olympian, Bruce brings exceptional enthusiasm, human qualities and leadership to our flagship crew program at MIT.

This year both women's soccer and men's volleyball were approved for intercollegiate status expanding the MIT intercollegiate component to a record MIT level (and probably a national high) of 36 sports. We are particularly pleased to upgrade the quality of these programs in the face of budget and staff reductions. A major long-range objective continues to be appropriate expansion of intercollegiate programs and the emphasis on the growth of women's athletics at MIT.

GENERAL PARTICIPATION OVERVIEW

Participation levels continue to climb in keeping with major long-term objectives of our Department. Total registrations in physical education reached an all-time high with more than one-third being voluntary non-credit - an impressive indication of the relevance and appeal of our programs to the important constituencies of graduate students and staff as well as post requirement undergraduates. MIT Club Sports had a record number 34 programs with almost 1,000 students participating including an increasing number of graduate students. Intramurals with one less program actually increased student participation almost 10% through a successful enrollment push in the six major sports of basketball, football, ice hockey, soccer, softball and volleyball. Intercollegiate athletic programs continued the high participation levels of previous years and will increase in future years as previously discussed.

General recreation expansion for the broader MIT Community also continues. The Class of 1974 Intramural Health Fitness Center usage has now reached 6,000 visits per month with an ever increasing number of women. Also General Skating has enjoyed a banner year with a primary reason the new and very successful MIT Skate Rental Service launched in 1984-85 through the 1984 Senior Class Gift. Faculty Athletic Card Sales are up +10% from last year.
PHYSICAL EDUCATION

Record total registrations include an all time high for IAP participation with an increase of over 20% in the last two years. The increased participation is directly attributable to improved program quality and a record number (55) program offerings under the creative and capable leadership of second year Director Gordon Kelly. Professor Kelly also was named 1985 New England Division III Track and Field Coach of the Year.

In addition to record enrollments two other significant highlights include the solidification of the MIT Health Fitness Test as a permanent part of our curriculum and Advanced Placement Exam procedure. It is our hope to gradually expand the awareness and impact of this program to a central role in the MIT Community. Next year the MIT Health Fitness Test will be available to the entire MIT Community under the auspices of the Sports Medicine Department and Coordinator Paul Grace. The testing will be administered at set times on a regular basis in the coeducational Sports Medicine Training Room.

The second highlight was successful implementation of changes in the MIT Swim Test procedures. The massive freshman test was moved earlier to Orientation Week with the entire full-time staff utilized to insure safety and efficiency. Over 650 freshman and women were tested - a significant increase over previous years.

MIT Physical Education Summer Program offerings continue to pick up interest and participation with masters swimming, exercise fitness, golf, scuba and tennis - all enjoying considerable popularity.

In addition to P/E Director Gordon Kelly and Assistant Director Professor Fran O'Brien we are particularly grateful for the dedication and professional competence of our 17 full-time and 28 part-time instructors who provide an atmosphere of caring and motivation that continues to stamp the MIT Physical Education Program as one of the finest of its kind in the nation.

CLUB ATHLETICS

MIT Club Athletics is oriented towards the involvement of graduate students and continues to push aggressively in that direction. This year Club Athletics under Professor Jack Barry's continued strong leadership enjoyed new highs with 35 programs (+3 vs. last year) and participants (985 vs. 857 last year).

The impressive figures do not include Club Football and Men's Ice Hockey which are now included in the intercollegiate statistics. Next year the Club Program will say goodbye to Women's Soccer and Men's Volleyball after a successful nurturing of these programs to intercollegiate status.

Next year we plan a reasonable increase in the Club Athletics budget to take full advantage of this cost effective component and to maintain appropriate program quality in coaching support and/or competitive opportunities.

INTRAMURALS

Coordinator Professor Dave Michael and Assistant Coordinator Professor Jean Heiney have done an effective job of motivating and focussing MIT student leadership as the crucial substance in the on-going popularity and effectiveness of the nationally recognized MIT Intramural Program. It is becoming more and more apparent that struggling or failing IM programs lack the involvement and drive of the participating students themselves. Our Department continues to work hard at the identification, support and recognition of our outstanding student leaders. They deserve most of the credit for the active and healthy MIT Intramural Program.

INTERCOLLEGIATE ATHLETICS

MIT Intercollegiate Athletics enjoyed considerable success in 1984-85 as well as a high level of participation (18% of the undergraduate student body). Of the 19 men's intercollegiate programs recording win-loss records 11 had winning records with an overall men's intercollegiate winning percentage of .543. The women's intercollegiate program enjoyed six winning seasons out of ten programs with an exceptional .606 winning percentage. Club Varsity Football and Men's Ice Hockey also enjoyed winning records while successfully and happily intergrating a growing percentage of graduate students.

Student success and satisfaction is a major goal as a supplement to the academic process in the building of confidence, competitive courage and a sense of teamwork and team building. This year five of our most impressive students received the prestigious distinction of selection as Academic All-American by the College Sports Information Directors of America. Over the three year period since 1982-83, a total of 20 MIT students have received this singular honor. This is an exceptional number for any institution and puts MIT with a handful of institutions nationally. Certainly this recognition is a wonderful credit to our students as well as to the diligence and commitment of Sports Information Director Ken
Cerino who oversees the applications and selections of these important awards.

All the men’s and women’s individual and team achievements and honors will be included in the MIT Archival Annual Statistics. By all accounts 1984-85 was an extraordinary year for our students and coaches.

Several coaches enjoyed their finest seasons in several years. First year Head Coach of Men’s Tennis and Squash, Professor Bob Bayliss gave men’s tennis its best season since 1969 while Head Coach of Women’s Tennis, Professor Candy Royer was named National Division III Coach of the Year by the Intercollegiate Tennis Association. Professor Royer’s combined 12-5 record was the best in MIT women’s tennis history. Third year Cross Country Coach, Instructor Halston Taylor enjoyed an undefeated fall season and combined with Head Coach of Track and Field, Professor Gordon Kelly to have undefeated winter and spring track seasons as well. Winter Track won the New England Division III Indoor Championship for the third time in five years. Men’s Baseball Coach, Professor Fran O’Brien had the most victories since 1976 and Heavyweight Crew under final year Coach Professor Peter Holland posted its best season in ten years beating Columbia, Coast Guard and Dartmouth. Golf with Head Coach, Professor Barry finished with an impressive 15-2 record placing third among 22 schools at the Massachusetts Intercollegiate Tournament. Men’s Club Ice Hockey had its fifth consecutive winning season under Coach Instructor Joe Quinn and Assistant Greg McManus. Instructor Eric Sollee and Men’s Fencing won the New England Championships and Men’s Wrestling enjoyed its fifth consecutive winning season under Coach Professor Tim Walsh.

Professor Jean Heiney and the Women’s Basketball had a second consecutive winning season while Women’s Fencing with Eric Sollee had a third straight winning season with a second New England Championship in three years. Women’s Volleyball has already noted the second place Division III national ranking. Since 1981 the women’s volleyball team has posted a remarkable 142 wins-20 losses for a .877 winning percentage.

NEW INTERCOLLEGIATE LEAGUE FORMATIONS FOR MIT

- The New England Women’s 6 - A women’s NCAA Division III playing conference with MIT’s Professor Jane Betts serving as the first president for a two year term. Charter members of the “New” 6 include Babson College, Brandeis University, MIT, Smith College, Wellesley College and Wheaton College.

MIT and Professor Betts were the driving force behind the creation of the conference calling together potential members for discussion of the concept then taking the leadership in moving to establish the conference. In 1985-86 the New England Women’s 6 will conduct championships in basketball, cross country and tennis.


The concept is to stretch and expose MIT Athletics to important metropolitan areas while bringing together institutions of similar athletic and academic philosophy. Our own Department is excited about the concept as is our new Director of Admissions, Michael Behnke.

We are still exploring schedule dates. Two other institutions, University of Rochester and Washington University in St. Louis, have expressed an interest in being included.

- Co-Educational Basketball Tournament Concept - On November 29-30, 1985 MIT will participate in the first co-ed basketball tournament at the University of Chicago. Included are Washington University in St. Louis and University of Rochester. The following year there will be a repeat co-ed tournament at MIT at which time MIT will assess the feasibility of staying with the tournament in subsequent years.

In addition to supporting equality of men’s and women’s athletics through an attention-getting co-ed tournament, the benefits to MIT include exposure to important urban areas and excellent competition among compatible institutions.

SPORTS PUBLICITY AND COMMUNICATIONS

The 1984-85 school year was the busiest and most exciting in the six year tenure of Director Ken Cerino. Working with a dedicated and loyal group of team managers, the Sports Publicity Office was able to maintain an efficient working relationship with coaches and other campus constituencies, the media (both on and off campus), and other groups in providing daily support for the quality programs of the Athletic Department.
The Sports Publicity Office assisted in the organization of three major championship events during the year: a) the NCAA Division III Women's Volleyball Tournament (Opening Round); b) the New England Division III Indoor Track and Field Championships, and c) the New England Track and Field Championships which MIT hosted for the first time since 1960. Ken Cerino and Larry Newman of New England Track edited a 40-page program for the New England meet which featured a color cover photograph of MIT co-captains Patrice Parris and Ronald Smith. The program also contained all results of all events of the New England since 1887.

Other important highlights include a feature in the 1985 National Director of College Athletics on the MIT's basketball team visit to India; b) a gymnastics demonstration between members of the MIT varsity men's/women's teams and the Tynan Community School of South Boston; c) the first-time publication of a baseball flyer, and support help for such events as the Community Service Fund, the MIT Activities Committee and the Bay State Games.

Probably the most satisfying aspect of the year was the 60 hometown press releases noting the accomplishments of MIT student-athletes and coaches. This area will always have a high priority in the Sports Publicity operation.

In 1985-86, the Sports Publicity Office hopes to finally produce a brochure which will be a handy reference guide listing pertinent information on the intercollegiate athletic program. We have been seeking input from the Admission's Office and Dean of Student's Affairs Office.

The Sports Publicity Office will continue to coordinate the various sports awards committees that do such an effective job of recognizing and honoring the significant achievements of our MIT students.

Director Ken Cerino has provided enthusiasm, good humor and exceptional dedication and leadership to this important MIT responsibility. He is equally recognized by his professional peers. He currently serves as workshop committee co-chairman of his national organization and treasurer of the New England Sportswriters Association.

ATHLETIC OPERATION AND FACILITIES

Assistant Director of Athletics, Professor Jane Betts provides firm and effective leadership of athletic facilities and their operation. I am also very grateful for her general support and counsel in all matters of the Department. Her report follows:

- **Completed Major Projects** - The shower/locker facility adjoining the JB Carr Tennis Bubble was completed in May. This facility includes toilet, shower and locker facilities for men and women, storage space for teaching and coaching equipment and a lobby in which the facility monitor will be stationed.

- **Projects in Progress** - Briggs Field - Area A: Preliminary work, (ground borings, presentations by manufacturers representatives, discussions regarding funding strategies) has taken place as the first steps in obtaining a synthetic surface on this heavily used lighted playing field.

  Briggs Field - Area B: A Department ad hoc committee met and agreed upon ways in which programs can be adjusted so that this area can be "rested" for 12 to 16 months. This activity area has deteriorated to the extent that it is considered unsafe for use. Resting the area will allow Physical Plant adequate time to work on the area and restore it to a safe playable field(s).

  The "Dance Studio" on the third floor of W-31 has been reduced in size in order to provide space for the expansion of the MIT Campus Police Department. The walls of three small storage rooms adjoining the studio will be removed this summer returning the studio to approximately its original size.

- **Projects Under Consideration** - Alumni Pool Renovation: expand the building to increase locker space for women, provide squash court ingress and egress for women, renovate the heating system and other mechanical aspects of the building.

  Renovate the locker rooms at Pierce Boat House to reduce the inequity of the male/female locker ratio and to improve the use and security of space resources and property.

  Expand locker/shower facilities in MIT Athletics Center. This project will include the re-assigning of some space and minor construction on the ground floor of the building.

  Build a press box in the bleacher area on Steinbrenner Stadium.

  Construct a new building at the duPont tennis courts. This building would provide storage, a
Projects Under Consideration (cont) - court monitoring/reservation station and an observation tower.

Replace the six Har-tru tennis courts with a synthetic surface that is compatible with all other MIT tennis surfaces outdoor and in the JB Carr Tennis Bubble.

- Physical Plant - The Athletic Department continues to supervise union labor at Pierce Boat House, Alumni Pool, and the athletic utility pool. This year Warren Leaman replaced Ray Smith as the boat house attendant and George D'Angelo replaced Joe Caseletto in the athletic utility group.

As problems with field maintenance increase the need for Athletic Department management of the grounds crew operation becomes increasingly apparent.

- Computer Component - The clerical staff continues to use the word processors in their daily activities. The computer function will be implemented this year in intercollegiate scheduling and in facility reservation procedures.

SPORTS MEDICINE/TECHNOLOGY HEALTH FITNESS

Coordinator of Sports Medicine, Paul Grace and his able staff of Kathy Davis, Gary Rizza and Del Smith have provided our Department and the entire MIT Community with caring, responsive and highly competent delivery of Sports Medicine services. The Sports Medicine component has emerged as a vital presence on the MIT Campus and we look forward to ever closer collaboration and mutual recognition/support with the MIT Medical Department in providing high quality care to the MIT Community.

Sports Medicine expanded protective coverage of athletic teams and increased efforts to disseminate conditioning methods for injury prevention. Service to student-athletes increased by over 14% to over 7,000 treatments in 1984-85. MIT Medical Department physicians examined 210 students through the Sports Medicine regular clinic and 109 patients were referred to Sports Medicine by the MIT Medical Department.

The Sloan School Senior Executive Health Fitness Program continued this past year with 75% of the Senior Fellows participating in the voluntary testing/assessment and individual recommendations for future fitness. This assessment/recommendation program is essentially replicated in the community-wide program to be available throughout 1985-86 on a regular basis under the supervision of the Sports Medicine Group with overall direction by the Department of Physical Education.

The Etonic Research Project was launched this year in collaboration with Professor Robert Mann of Mechanical Engineering. The project is sponsored under a grant from Colgate Palmolive Company. The focus of the research is the biomechanics of the human foot and ankle and how they are influenced by the shoe in sports activities.

ROYCE N. FLIPPIN, JR.
EXHIBIT I
MIT ATHLETIC PROGRAM PARTICIPATION

<table>
<thead>
<tr>
<th>Report Year</th>
<th>1984-85</th>
<th>1983-84</th>
<th>1982-83</th>
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</thead>
<tbody>
<tr>
<td>STUDENT ENROLLMENT</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(October Figures - includes Specials)</td>
<td></td>
<td></td>
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<tr>
<td>Undergrad Women</td>
<td>1,157</td>
<td>1,090</td>
<td>1,048</td>
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<tr>
<td>Undergrad Men</td>
<td>3,379</td>
<td>3,512</td>
<td>3,571</td>
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<tr>
<td>TOTAL</td>
<td>4,536</td>
<td>4,602</td>
<td>4,619</td>
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<tr>
<td>Graduate Women</td>
<td>1,054</td>
<td>976</td>
<td>929</td>
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<tr>
<td>Graduate Men</td>
<td>4,036</td>
<td>3,999</td>
<td>3,927</td>
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<tr>
<td>TOTAL</td>
<td>5,090</td>
<td>4,975</td>
<td>4,856</td>
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<tr>
<td>GRAND TOTAL STUDENTS</td>
<td>9,626</td>
<td>9,577</td>
<td>9,475</td>
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STUDENT PARTICIPATIONS
(Includes Multiple Activity Duplication)

1. PHYSICAL EDUCATION

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<tr>
<th>Total Registrations</th>
<th>6,589</th>
<th>6,401</th>
<th>6,521</th>
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<tbody>
<tr>
<td>(Undergrad)</td>
<td>(5,298)</td>
<td>(5,149)</td>
<td>(5,384)</td>
</tr>
<tr>
<td>(Grad)</td>
<td>(909)</td>
<td>(848)</td>
<td>(827)</td>
</tr>
<tr>
<td>(Staff)</td>
<td>(382)</td>
<td>(404)</td>
<td>(310)</td>
</tr>
</tbody>
</table>

2. INTRAMURALS (M/W & COED)

| Programs | 24 | 25 | 29 |
| Teams | 1,180 | 1,180 | 1,229 |
| Students | 11,779 | 10,845 | 11,876 |

3. CLUBS

| Programs | 35 | 32 | 32 |
| Students | 985 | 857 | 812 |

4. INTERCOLLEGIATES

| Women's Programs | 11 | 11 | 11 |
| - Student Participants | 205 | 206 | 195 |
| - Varsity Letter Awards | 112 | 111 | 119 |
| Men's Programs | 23(1) | 23(1) | 21 |
| - Student Participants | 614 | 596 | 609 |
| - Varsity Letter Awards | 321(2) | 267 | 259 |

(1) Increase from 21 to 23 reflects inclusion of Club Varsity Football and Men's Ice Hockey beginning 1983-84
(2) Varsity letter increase reflects first time inclusion of Club Varsity Football and Men's Ice Hockey
EXHIBIT II
MIT DEPARTMENT OF ATHLETICS

FIVE YEAR LONG TERM STRATEGIC OBJECTIVES (JUNE 1985)

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

- Improve minority faculty/staff representation.

- Continue to expand one of the largest percent participation programs in the United States in intramurals, club offerings, intercollegiate teams and general recreation opportunities; emphasize continued growth of women's athletics.

- 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.

- Develop external resources for improvement of existing facilities. Plan and promote implementation of Phase III new facilities, artificial field surfaces and planned renovations.

- Gradually consolidate responsibility for all outside field maintenance and building services associated with athletic programs.

- Reorganize office space and work locations for improved efficiency and cooperation within the Department.
Medical Department

This has been a most eventful year, important for several things which happened, one which didn't, and some which have yet to occur. For the first time in its history, MIT includes among its resources a fully licensed, JCAH accredited hospital. The long sought accreditation by the Joint Commission on Accreditation of Hospitals was achieved this year following a full day fact-finding site visit conducted by four surveyors. Our compliance with national standards of excellence in more than 20 areas of performance was assessed, and we were granted accreditation for the maximum term of three years.

As has been previously noted, this accomplishment represents the last act of a drama which started several years ago. Many have acted important roles, with great energy and enormous dedication on the part of everyone in the Department. This judgment by an outside evaluator that the quality of the care we provide is high is gratifying.

A major preoccupation for a group of us has been the effort to restructure the governance of the Medical Department. The previous arrangement among the Department's leadership, the MIT Administration, the "governing body" (the Medical Administrative Board), and other entities was ill-defined, loosely-structured and fragile. A group comprised of the Medical Director (M.H.Rodman), the Associate Director for Administration (L.H.Bishoff), the Vice President to whom the Department reports (C.B.Simonides) and the then Director of Personnel (J.J.Culliton) worked for well over a year to develop a structure for the governance of the Department. It embodies a Medical Management Board which functions as a Board of Trustees for the Department within the structure of MIT. That Board has responsibility and exercises authority over the Department, although ultimate responsibility rests with the MIT Corporation and executive authority flows through the President and his designees.

A new position is also created, that of Executive Director. This title designates the chief administrative officer within the Department. In addition, the by-laws entertain the possibility that either the Medical Director or the Executive Director may be the Department Head.

There is, in addition, a Hospital Board which is comprised of members of the Medical Management Board. This body has responsibility for the Department's functions as a licensed and accredited hospital and plays an important role in the appointment and reappointment of members of the medical staff.

The noteworthy non-occurrence was a much feared measles epidemic. Data that we had collected in February 1984 indicated that as many as 15% of the undergraduate population might be susceptible to measles. This led to the recommendation, in February 1985, that measles and rubella immunity be required for all freshmen entering MIT in September 1985. Just as that recommendation was being formulated, there was an epidemic of measles at Boston University with over 60 confirmed cases.

News of the first case at MIT stimulated the formation of a group in the Department to keep abreast of the situation and do whatever necessary to limit the spread of the disease here. The group (Laurence H. Bishoff, Dr. Michael Kane, Deborah Dacus, George Petievich, Dr. John Moses, Dr. Mark Goldstein) determined the most vulnerable members of the MIT community to be those born after 1956 who had not had measles and had either not been vaccinated or had been vaccinated inadequately. A mass immunization program for these people was undertaken.

Special efforts were directed at notifying the contacts of the known case and the second one that soon followed, as well as those students who had been found in the previous (February 1984) survey to be susceptible. Publicity through Tech Talk, The Tech, television stations and Boston newspapers was very effective, and the first 100 vaccinations were given over the weekend following the first announcement, even before the immunization program had officially started. Over 1300 people were vaccinated, records of the event kept, the safest vaccine (monovalent) used and only a single reaction (allergy) noted. The tireless, committed members of the staff who worked effectively to bring this about included physicians, nurses, administrators, receptionists and medical record personnel. Only the Medical Director, who was out of town, could not claim any of the praise which even The Tech, in an editorial, offered. There were no further cases beyond the two.

The event which has yet to occur as this is written also involves the Medical Director. On July 1, he starts a year's sabbatical leave - the first time this boon has ever been claimed in this Department. His absence offers the occasion for another 'first': the Acting Department Head will be a non-physician. Laurence H. Bishoff will add the responsibilities of Acting Head of the Department to those of Executive Director, a position he assumed under the new by-laws.
Acting as Medical Director for the year will be Dr. Michael A. Kane, who as Associate Medical Director has acquired knowledge and experience in the role he will be playing.

The Department, then, will rest securely in skilled and experienced hands; the major risk is to the perception of the importance of the current incumbent.

**Staff Changes**

<table>
<thead>
<tr>
<th>APPOINTMENTS</th>
<th>Physician</th>
<th>Physician</th>
<th>Nurse Practitioner</th>
<th>Nurse Practitioner</th>
<th>Assistant Radiation Protection Officer</th>
<th>Surgeon-in-Chief</th>
<th>Nurse Practitioner</th>
<th>Dental Hygienist</th>
<th>Physician</th>
<th>Physician; Special Assistant to Chief Administrative Officer</th>
<th>MIT Health Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynn M. Cleary</td>
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</table>

<table>
<thead>
<tr>
<th>RESIGNATIONS</th>
<th>Assistant Radiation Protection Officer</th>
<th>Nurse Practitioner</th>
<th>Dentist</th>
<th>Obstetrician/Gynecologist</th>
<th>Biologist</th>
<th>Dermatologist</th>
<th>Dermatologist</th>
<th>Dentist</th>
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</thead>
<tbody>
<tr>
<td>Paul Black</td>
<td>Micahel N. Hatton</td>
<td>Linda L. Henlotter</td>
<td>Geoffrey E. Linburn</td>
<td>Brenda Lindemann</td>
<td>John V. Pikula (Retirement)</td>
<td>Kathryn N. Post</td>
<td>June W. Pryor (Retirement)</td>
<td>Colleen Ryan</td>
</tr>
<tr>
<td>Peggy Lee Coulter</td>
<td>Michael N. Hatton</td>
<td></td>
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<tr>
<td>Michael N. Hatton</td>
<td>Linda L. Henlotter</td>
<td>Geoffrey E. Linburn</td>
<td>Brenda Lindemann</td>
<td>John V. Pikula (Retirement)</td>
<td>Kathryn N. Post</td>
<td>June W. Pryor (Retirement)</td>
<td>Colleen Ryan</td>
<td>Albert B. Samaraweera (Retirement)</td>
</tr>
<tr>
<td>Geoffrey E. Linburn</td>
<td>Brenda Lindemann</td>
<td>John V. Pikula (Retirement)</td>
<td>Kathryn N. Post</td>
<td>June W. Pryor (Retirement)</td>
<td>Colleen Ryan</td>
<td>Albert B. Samaraweera (Retirement)</td>
<td>Frederick Schaeffer</td>
<td>Steven K. Shama</td>
</tr>
</tbody>
</table>

**Level of Activity**

We are currently experiencing a frustration which will be understood by many at MIT. Data which has been acquired concerning patient visits is not retrievable in a way which permits an annual summary at this time. The total of the first three quarters of this year and the last quarter of last year is available but is not useful except to indicate that the general level of utilization (120,550 visits to the ambulatory services annually) is about the same as it has been.

When the program which is needed to liberate the entrapped information is completed, we will have an instrument which will provide very useful data in timely fashion.

We do have some thanatological data: 63 deaths were reported among MIT employees this year. Of these, 24 were the result of heart disease, 23 from cancer, two from chronic lung disease, three the result of accidental injury and 11 from a variety of other causes.
Environmental Medical Service

Richard I. Chamberlin, Associate Director of this service, notes that activity in all areas (Industrial Hygiene, Radiation Protection, and Biohazards Assessment) is at an all-time high. With the coming on-line of the Whitehead Institute, expansion of Draper Laboratory, and added requests for assistance on campus, the demands on personnel have been extreme.

The on-campus activities include a significant increase in requests for assistance with departmental safety training programs. This reflects the suggestion of the Institute Council on Environmental Health and Safety that each department emphasize training of personnel in its safety programs, as well as MIT's commitment to satisfy the intent of the Massachusetts Right to Know Law.

Continuing issues of great concern include potential asbestos exposure, the "tight building" syndrome, potential effluent reentry, the disposal of hazardous and radioactive waste, and the short-term but time consuming investigations of complaints about "odors". No regional program for the disposal of radioactive waste has yet appeared; the availability of the present federal site will, it appears, be extended for a while. Meanwhile, earnest efforts to reduce the volume of materials to be disposed of are under way.

This year also saw the revival of special OSHA regulations for laboratories. These are, for the most part, in keeping with present MIT and EMS policies and operating procedures and represent an improvement over the existing standards. If enacted, the regulations would increase even further the demands on EMS. It is essential that the participation of the Environmental Medical Service in activities required by the burgeoning body of regulations not be allowed to compromise its basic character - that of the helpful consultant offering guidance and assistance in complying with regulations imposed by others, rather than the policeman who enforces them.

Social Work Service

Despite problems with the information-processing system in the Department, this Service has implemented a system which provides better monitoring of the status of patients as well as the status of the case record. Statistical review of over-all activity for both the Social Work Service and the Institute's Personal Assistance Program is supported by this system.

That level remains fairly steady and reflects primarily the availability of clinical time. The excess of demand over the available time is monitored as it is reflected in the waiting time until the next available appointment. Fortunately, during much of this past year an additional experienced social worker – Wendy Rosen – was available as part of her Ph.D. internship at the Smith College School of Social Work.

The Institute Personal Assistance Program continues at a very active pace. There have been over 500 people referred to the program since its inception, and the recovery rate continues at a most impressive two out of three.

Psychiatry Service

During the prior two years, an increase in the utilization of hospitals for the treatment of psychiatric illness had been observed. Reasons for the increment were not apparent. For similarly poorly understood reasons, both the total number of admissions to mental hospitals and the total number of days of hospitalization decreased significantly last year. Although we fancy the notion that the efforts exerted in maintaining liaison with the outside hospitals by Dr. Wade Rockwood and Ms. Julie Roberts paid off, we may merely be observing the natural history of some other phenomenon.

The over-all decrease in number of hospitalizations reflects the net change of a 39% drop among students and a 29% rise among Health Plan members. The number of days of hospitalization fell to roughly 64% of the previous year's level. The decrease also occurred in the Department's Inpatient Unit. Lest we be misled, however, it must be noted that the number of hospitalizations and days in hospital for psychiatric illness in this community continue to exceed the experience of many HMOs by a factor of nearly three.

MIT Health Plan

Laurence H. Bishoff, Chief Executive Officer of the MIT Health Plan, offers the following:

"The MIT Health Plan broke through the 4000 subscriber barrier this year. By June 1, 1985, 4192 contracts were in effect, up 6% over the beginning of the year. With an average of 2.1 members covered under each contract, 8735 people were cared for under the Plan. Fifty-two percent of eligible employees on the main campus belong to the MIT Health Plan; it is now the most popular health benefits program."
"Hospital utilization by Plan members remained under control at 338 days per 1000 members. This record is significantly lower than the national average for all HMOs and for plans of similar locale, size or structure. The year end fiscal results should reflect this positive experience.

"Despite some technical problems delaying start-up, a new network of microcomputers gives the Department excellent biographic data on our complicated patient database. The state of the art network is also very cost effective. We look forward to the extension of the system to appointment, fiscal and record management activities in the coming year.

"Dr. John C. Kryder joined our management ranks this year sharing his time between planning activities and clinical care responsibilities as a primary physician. He has inaugurated a major study on health care costs at MIT, in support of the MIT Benefits Office, as well as the Medical Department. We are indeed fortunate to have obtained his services, confirming the wisdom of our participation in the Harvard-Mount Auburn Hospital Primary Care Residency Training Program in which he was a resident.

"The achievement of accreditation by the Joint Commission on Accreditation of Hospitals - the conclusion of a long term major departmental goal - is due in large measure to the collective efforts of this excellent administrative staff. They can all justifiably take great pride in the results of their efforts."

MELVIN H. RODMAN, M.D.
This was a very satisfying year at MIT Press. We published 143 titles: 98 original publications, and 45 paperbacks reprinted from our own hardcover backlist. Eleven of the original publications were issued simultaneously in hardcover and paperback, and six were original paperbacks. A total of 464,000 copies of our books were sold, up 12.6 percent from last year. Backlist sales were up 17 percent. Domestic sales improved by 10 percent. Sales to Europe improved by 17 percent, to Japan by 13.5 percent, and to Canada by 4.3 percent. Overall, international sales constituted 24 percent of total sales. In Journals, our total subscription level reached 42,000, and sales were up 18 percent.

Some of our best sellers from this year's list were:

Abelson & Sussman  Structure and Interpretation of Computer Programs
Altshuler et al.  The Future of the Automobile: The Report of MIT's International Automobile Program
Braitenberg  Vehicles: Experiments in Synthetic Psychology
Branzi  The Hot House: Italian New Wave Design
Cohen  Herbert Bayer: The Complete Work
Dennett  Elbow Room: The Varieties of Free Will Worth Wanting
Forester  Effective Cycling
Jenkins & Krane  Holle Frampton: Recollections/Recreations
Killian  The Education of a College President: A Memoir
Krauss  The Originality of the Avant-Garde and Other Modernist Myths
Meehan  The Copyright Book: A Practical Guide, 2nd Ed.
Strong  The Management Challenge: Japanese Views
Thurow

Books written or edited by MIT faculty:

Abelson & Sussman  Structure and Interpretation of Computer Programs
Altshuler et al.  The Future of the Automobile: The Report of MIT's International Automobile Program
Brady & Paul  Robotics Research: The First International Symposium
Diamond  A Search-Equilibrium Approach to the Micro Foundations of Macroeconomics
Elliot & Kerr  Hinge: Discoveries from Galileo to Voyager
Fisher  Antitrust and Regulation: Essays in Memory of John J. McCuan
Helpman & Krugman  Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy
Houghton  Physical Meteorology
Jackiw et al.  Shelter Island II
Katz  Shifting Gears: Changing Labor Relations in the U.S. Automobile Industry
Killian  The Education of a College President: A Memoir
Kindleberger  Multinational Excursions
Kochan  Challenges and Choices Facing American Labor
Mason & Salisbury  Robot Hands and the Mechanics of Manipulation
Roads & Strawn  Foundations of Computer Music
Steinfeld  Molecules and Radiation: An Introduction to Modern Molecular Spectroscopy, 2nd Ed.
Taylor  The Internal-Combustion Engine in Theory and Practice (Revised)
Thurow  The Management Challenge: Japanese Views
Wildes & Lindgren  A Century of Electrical Engineering and Computer Science at M.I.T., 1888-1982

Financial results continued to be positive. Net sales were $5,930,000 in our book division and $3,000,000 in Journals. The Press closed its fiscal year with a $17K net gain from operations, as compared with a $56K gain from operations last year. Our sales volume was 10.6 percent above fiscal 1984, while operating expenses grew by 10.2 percent. Net cash flow was $355K on $9.3 million cash receipts, as compared with $369K on $7.8 million in 1983. The Press was once again able to reduce its working capital advance from the Institute.
Changes in personnel included several promotions from within in the management of our Subsidiary Rights and Publicity Departments, and new faces in Acquisitions, Design, Sales, Editorial, Production, and Fulfillment. We hired a new acquisition editor in economics to replace the current editor, who will move to Oxford, England, in August 1985 to set up a European editorial office for the Press.

The Journals Division showed a significant profit for the fourth year in a row. The departure of Cell, which will become an independent publication in January 1986, will have a significant impact on the size and profitability of the Journals operation; but we expect to add a number of journals over the next two years, and we are confident that Journals will break even during this period and then begin showing a profit again in 1986.

The MIT Press Bookstore exceeded expectations once again. Total sales in Kendall Square were in excess of $190,000.

COMPARATIVE OPERATING RESULTS

(in thousands)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Fiscal Year</th>
<th>Fiscal Year</th>
</tr>
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<tbody>
<tr>
<td>Actual</td>
<td>Actual</td>
<td>Actual</td>
</tr>
<tr>
<td>1985</td>
<td>1984</td>
<td>1983</td>
</tr>
<tr>
<td>Total Net Book Sales</td>
<td>$5,930</td>
<td>$5,353</td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>2,666</td>
<td>2,423</td>
</tr>
<tr>
<td>Gross Margin on Sales</td>
<td>3,264</td>
<td>2,930</td>
</tr>
<tr>
<td>Other Pub. Income</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>Bookstore Net</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Total Income</td>
<td>3,323</td>
<td>2,991</td>
</tr>
<tr>
<td>Operating Expense</td>
<td>3,407</td>
<td>3,092</td>
</tr>
<tr>
<td>Net Books Division</td>
<td>( 84)</td>
<td>(101)</td>
</tr>
<tr>
<td>Journals Surplus</td>
<td>101</td>
<td>157</td>
</tr>
</tbody>
</table>

NET $ 17 $ 56 $( 50)

The Press received approximately $50,000 in subventions aiding the publication of four of its titles during the past year. Sources of subvention included the J. Paul Getty Trust, the Burndy Library, the Margaret T. Morris Foundation, and the National Endowment for the Arts. These grants helped make possible the publication of Archer/ The Literature of British Domestic Architecture, 1715-1843, Staudenmaier/ Technology's Storytellers: Reweaving The Human Fabric, Stoeckle & White/ Plain Pictures of Plain Doctoring, and the paperback edition of Craig/ The Federal Presence.

Press books won several notable awards this year. Game Gheory in the Social Sciences: Concepts and Solutions by Martin Shubik was awarded the Frederick W. Lanchester Prize of the Operations Research Society of America. A Pictorial History of Chinese Architecture by Liang Ssu-Ch'eng was chosen as best new book in architecture and urban planning by the American Association of Publishers. And Campus: An American Planning Tradition by Paul Venable Turner, which the Press copublished with the Architectural History Foundation, received the Alice Davis Hitchcock Award of the Society of Architectural Historians.

Faculty serving on The MIT Press editorial board in 1984-1985 were: Professors Harold Abelson, Peter Elias, John de Monchau, Loren R. Graham, Richard Held, John P. Longwell, Daniel Osherson, 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 John M. Deutch, Dean, School of Science; Ann F. Friedlaender, Dean, School of Humanities & Social Science; Alvin J. Silk, Associate Dean of the Sloan School; Jeremiah Kaplan, President, Macmillan Publishing Co., Inc.; Norman Pomerance, Vice President, General Books Group, Harper & Row; Jack Schuman; 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.

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Achinstein & Hannaway: Observation, Experiment, and Hypothesis in Modern Physical Science
Aoun: A Grammar of Anaphora
Apel: Understanding and Explanation
Archer: The Literature of British Domestic Architecture, 1715-1842
Beaver et al.: Talking Minds: The Study of Language in Cognitive Sciences
Blau: Architects and Firms: A Sociological Perspective on Architectural Practice
Cresswell: Structured Meanings: The Semantics of Propositional Attitudes
Dallmayr: Polis & Prazia: Exercises in Contemporary Political Theory
Fauconnier: Mental Spaces: Aspects of Meaning Construction in Natural Language
Hahn: Equilibrium and Macroeconomics
Herbert: The Dream of the Factory-Made House
Kolbe et al.: The Cost of Capital: Estimating the Rate of Return for Public Utilities
Meyer et al.: Deregulation and the New Airline Entrepreneurs
Narens: Abstract Measurement Theory
O'Donnell: Equational Logic as a Programming Language
Shubik: A Game-Theoretic Approach to Political Economy
Stalnaker: Inquiry
Staudenmaier: Technology's Storytellers: Reweaving the Human Fabric

New hardcover books for trade and general audiences included:

Altshuler et al.: The Future of the Automobile: The Report of MIT's International Automobile Program
Braitenberg: Vehicles: Experiments in Synthetic Psychology
Branzi: The Hot House: Italian New Wave Design
Cohen: Herbert Bayer: The Complete Work
Dennett: Elbow Room: The Varieties of Free Will Worth Wanting
Elliot & Kerr: Rings: Discoveries from Galileo to Voyager
Forester: Effective Cycling
Gadamer: Philosophical Apprenticeships
Hirschhorn: Beyond Mechanization: Work and Technology in a Postindustrial Age
Jenkins & Krane: Holli Partington: Recollections/Recreations
Killian: The Education of a College President: A Memoir
Krauss: The Originality of the Avant-Garde and Other Modernist Myths
Marzona & Fricke: Bauhaus Photography
Meehan: The Atom and the Fault: Experts, Earthquakes, and Nuclear Power
Quine: The Time of My Life: An Autobiography
Stoeckle & White: Plain Pictures of Plain Doctoring
Thurow: The Management Challenge: Japanese Views

Books published and directed primarily at the textbook market included:

Beck: Hematology, 4th Edition
Cassell: Talking With Patients
Houghton: Physical Meteorology
Kochan: Challenges and Choices Facing American Labor
Reid: Understanding Buildings: A Multidisciplinary Approach
Steinfeld: Molecules and Radiation: An Introduction to Modern Molecular Spectroscopy, 2nd Ed.
Vidyasagar: Control System Synthesis: A Factorization Approach

The Bradford Books imprint of the MIT Press published nine books. The ACM Doctoral Dissertation series published four books, including Reduced Instruction Set Computer Architectures for VLSI by Manolis G. H. Katevenis, the winner of the 1984 Doctoral Dissertation Award. Our other series also flourished, and our new set of series in computer science got off to a distinguished start.
Acquisition editors at the MIT Press include: Frank Satlow (Engineering & Computer Science); Laurence Cohen (Sciences, Engineering, Linguistics, & Philosophy); Roger Conover (Architecture & Design Arts); Terry Vaughn (Economics & Management); Robert Bolick (Oxford); Harry & Betty Stanton (Cognitive Sciences, Bradford Books); and Terry Ehling (Computer Science).

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. Computergraphics, our typesetting facility, under the management of Miriam Palmerola, produced 48 books while grappling with alternative ways to deal with manuscripts presented on diskettes and magnetic tapes. 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 American Institute of Graphic Arts, and the Art Director's Show of Boston; three new designers and a new technical assistant joined the department this year.

BOOK SALES

Under the direction of Tom McCorkle, marketing manager, domestic sales increased nine percent over last year. Sales in the United States and Canada by distribution channel were as follows:

<table>
<thead>
<tr>
<th>Customer Type</th>
<th>Fiscal Year 1985 (in thousands)</th>
<th>Fiscal Year 1984 (in thousands)</th>
<th>Fiscal Year 1983 (in thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Bookstore</td>
<td>$1,154</td>
<td>$1,105</td>
<td>$ 885</td>
</tr>
<tr>
<td>Retail Bookstore</td>
<td>1,275</td>
<td>1,159</td>
<td>1,108</td>
</tr>
<tr>
<td>Wholesale/Jobber</td>
<td>1,250</td>
<td>1,163</td>
<td>1,042</td>
</tr>
<tr>
<td>College/University Lib.</td>
<td>129</td>
<td>136</td>
<td>123</td>
</tr>
<tr>
<td>Direct Mail</td>
<td>426</td>
<td>412</td>
<td>388</td>
</tr>
<tr>
<td>Other</td>
<td>500</td>
<td>357</td>
<td>346</td>
</tr>
<tr>
<td>Totals</td>
<td>$4,734</td>
<td>$4,332</td>
<td>$3,892</td>
</tr>
</tbody>
</table>

This has been another good year, with healthy increases both domestically and internationally. Especially encouraging is the increase in the number of books we sold, from 435,000 to 465,000, or about seven percent.

International Sales and Subsidiary Rights

International sales, which constituted 24 percent of total FY 1985 book sales, increased 14 percent over the previous year. An especially strong increase of 58 percent was achieved in the category listed below as "Rest of Asia and Other." This category includes direct cash sales to foreign customers, along with sales to booksellers in the more difficult market areas of Asia. Sales through our London marketing office, which serves primarily the U.K. and Continental Europe, registered a healthy 17 percent increase. These sales increases are especially noteworthy because they came in spite of the year's unusually high value of the dollar against other currencies.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Australasia</td>
<td>$ 32,300</td>
<td>$ 35,000</td>
<td>$ 36,000</td>
</tr>
<tr>
<td>Canada</td>
<td>236,800</td>
<td>229,000</td>
<td>206,000</td>
</tr>
<tr>
<td>Japan</td>
<td>284,900</td>
<td>251,000</td>
<td>194,000</td>
</tr>
<tr>
<td>Rest of Asia/Other</td>
<td>172,100</td>
<td>109,100</td>
<td>119,000</td>
</tr>
<tr>
<td>Latin America</td>
<td>24,500</td>
<td>47,500</td>
<td>27,000</td>
</tr>
<tr>
<td>UK/Europe/Africa/Mideast</td>
<td>656,300</td>
<td>560,600</td>
<td>580,000</td>
</tr>
<tr>
<td>Totals</td>
<td>$1,408,900</td>
<td>$1,232,200</td>
<td>$1,162,000</td>
</tr>
</tbody>
</table>
Our subsidiary rights effort, under Trudihope Schomowitz, say 13 titles sold to bookclubs and 16 translation contracts signed. Major excerpt sales included a cover piece from Diamond and Bates/ The Spot in the Boston Sunday Globe Magazine and several excerpts from Stoeckle & White/ Plain Pictures of Plain Doctoring.

### Subsidiary Rights Income FY 1983-1985

<table>
<thead>
<tr>
<th></th>
<th>Fiscal Year 1985</th>
<th>Fiscal Year 1984</th>
<th>Fiscal Year 1983</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translation Rights</td>
<td>$28,511</td>
<td>$26,592</td>
<td>$28,335</td>
</tr>
<tr>
<td>Book Club Rights</td>
<td>12,533</td>
<td>11,224</td>
<td>12,647</td>
</tr>
<tr>
<td>Reprint Rights</td>
<td>18,334</td>
<td>19,979</td>
<td>15,844</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>$59,379</strong></td>
<td><strong>$57,795</strong></td>
<td><strong>$56,826</strong></td>
</tr>
</tbody>
</table>

### Direct Mail and Promotion

Under the direction of Brooke Stevens, promotion manager, direct mail sales for the year were $426,180, a five percent increase over last year. A catalog for architecture books and a brochure for economics books were the most successful subject area mailings: sales for each of them were almost double any previous year’s totals. Our forthcoming “Encyclopedia of Materials Science & Engineering” was promoted heavily in the spring through an announcement mailing, space ads, and a 24-page prospectus mailed to 65,000 prospects. The encyclopedia, a co-publication with Pergamon Press, will be shipping in the spring of 1986.

Text promotions this year were greater in number than in any previous year: 20 promotional pieces were mailed to over 48,000 professors in the fields of labor studies, architecture, philosophy, medicine, mechanical engineering, meteorology, physical chemistry, and computer science.

The Press is attending more professional meetings than in prior years, particularly in computer science and in the cognitive sciences.

Press books received over 1,500 reviews in scholarly and technical journals, newspapers, and magazines. The New York Times reviewed Richard Meehan's/ The Atom and the Fault; The Hot House by Andrea Branzi; Rings/ by James Elliot and Richard Kerr; and Arthur A. Cohen's book on Herbert Bayer. MIT graduate Meehan's book was also reviewed in Science, along with The Education of a College President: A Memoir by James R. Killian, Jr. Vehicles by Valentino Brajtenberg received major reviews in Nature and in Scientific American, which also gave major coverage to Rings.

### Journals

The Journals Division had gross sales of $3.0 million and closed the fiscal year with a net surplus of $101,000. $164,659 was added to the reserve account (unearned subscription income), bringing the total reserve to $194,661, an increase of 16 percent over fiscal year 1984.

The journal fulfillment system, Scribe, was upgraded with entirely new software, giving us greater storage capacity, better manipulation of subscriber data and financial information, and a bookstore single-copy sales package. Our total subscriber level reached 42,000 during FY 85.

Cell and Design Quarterly both added over 1,000 subscribers for the second year in a row. Levels for the other journals in the program also increased in FY 85. The first comprehensive journals catalog was produced last fall and mailed to 5,200 booksellers, librarians, and subscription agencies.

Our journals continue to receive recognition in the field: Robotics Research 3:2, Special Issue on "Legged Locomotion" and an accompanying videotape, received an honorable mention as best single issue of a journal from the American Association of Publishers. Harvard Architecture Review #4 received the best single issue award from AAP and received a display entry for excellence in graphic arts in the New England Book Show. The Harvard Architecture Review #4, Robotics Research, Places, and Computer Music Journal were included in the Association of American University Presses' traveling book exhibit and 1985 Book Show catalog.

International Security received a $150,000 grant from the MacArthur Foundation to enhance its editorial coverage. October received $20,000 from the Getty Trust for a special issue of the translated works of Georges Bataille. The final portion of the System Development Foundation grant were used to subsidize the continuing production of the special videotape for Robotics Research.
Four journals will be leaving the program: *Space & Society*, *Milbank Memorial Fund Quarterly*, *Harvard Architecture Review*, and *Cell*. The other journals in the program are *The Drama Review*, edited by Michael Kirby; *International Organization*, edited by Peter Katzenstein; *Journal of Interdisciplinary History*, edited by Robert Rotberg and Theodore Rabb; *Linguistic Inquiry*, edited by Jay Keyser; *Mimar*, edited by Hasan Khan; *Perspecta*, sponsored by the Yale School of Architecture; *VIA*, sponsored by the Department of Architecture, University of Pennsylvania; and *The Washington Quarterly*, edited by Richard Bissell.
There was ample evidence during the past year that MIT enjoys a major reputation as a maker of news for America's popular media. A major achievement was promotion by the News Office's China Altman of the dedication of the new List Center for the Arts. News media in New England and New York gave the story major coverage as did wire services providing news to media elsewhere. Issues relating to the Strategic Defense Initiative, or Star Wars, also kept MIT people prominent in the news during the year. A complete inventory of the stories that put MIT in the public eye during the year would be too long. But a random sampling might include such national stories as: Lee Iacocca's commencement address. A macro-engineering conference paper about 21-minute coast-to-coast transportation in an underground vacuum tube. A symposium where MIT veterans of the Manhattan Project recalled the atom bomb 40 years later. Alan Guth's new "inflation" theory about the beginnings of the universe. Computer voice recognition. Our EECS overenrollment. MIT reactions to Reagan Administration plans to restrict openness of U.S. scientific efforts and other plans to cut back federal student aid. Student protests over South African apartheid. MIT's tuition, the nation's highest. Vogue's interview with Alumni Assn. President Mary Frances Wagley. A PBS NOVA program on Dr. Edgerton. Identification of T Cell receptor site chemistry by S. Tonegawa. Calvin Campbell's nationally syndicated picture of Haystack antenna panels being replaced.

All told during the year, the News Office issued 226 news releases. These included 37 dealing with music, 25 with art, six with drama, three with literature, two with dance, and five with related cultural activities for a total of 79, more than twice the output for the previous year, all the result of extraordinary efforts and organization by Ms. Altman. In addition, Ms. Altman initiated a system of periodic calendar-type releases that kept MIT cultural events before the press and before the public. The news release total for the year also included 27 releases dealing with the substance of research at MIT, also an increase over the previous year, due to the efforts of the News Office's Robert DiIorio and Charles Ball.

Tech Talk, under editor Joanne Miller, appeared 37 times during the year with a total of 304 pages. In addition, Tech Talk carried four special supplements: Arts in the News, Report of the President, Committees of the Institute, and the MIT Affirmative Action Plan.

There were two support staff changes. Eugene de Mesne joined the office as administrative secretary and Sharon Davis came to us as a reporter/writer for Tech Talk. Both succeeded predecessors who left. Meantime, Lynn Heinemann rendered effective support for Tech Talk assembly and production.

A final note. This was our first full year of having word processors for the writing staff. We wonder now how we got along without them. The experiment has been a major success.

ROBERT M. BYERS
Office of Admissions

This has been a year of change and inquiry.

Peter H. Richardson retired as Director of Admissions and took the post of Director of Admissions at Vermont Law School. Margo Tyler accepted a new position as Coordinator of the Sloan Masters Program, Brenda Hambleton received a Sloan Degree in June and will work with a marketing firm, Nelson Armstrong will also leave this year.

Many issues were raised this year by an active Committee on Admissions and Financial Aid, chaired by Professor Ken Manning. The question of over enrollment in Electrical Engineering/Computer Science perhaps the most important. Brought before the faculty, CUAFA was given the responsibility to access the need for a restriction at the freshman level over a two year period. There has been much discussion as to the model the Admissions Office might use in such an eventuality, but fortunately the numbers stabilized and no restriction is necessary for the present. The class which entered in September of 1984 and the class to enter in September 1985 are, therefore, without restriction.

College transfers continue to be denied the opportunity to register in VI and that restriction will be in effect for the next year as well. Among other issues being addressed is the area of financial aid and financial aid strategies. Differential packaging, self-help levels, outside scholarship procedures, no-need, admit-deny, and methods used by our competition to attract and meet the financial aid need of our applicants have been agenda items for discussion. Of particular concern has been the need of minority applicants. Efforts to attract a larger pool of minority applicants must be increased. We must develop new procedures which will help us to understand and work toward better representation in the entering classes. An increase in staff has been approved to provide a sustained effort.

There were discussions among the faculty and staff this year concerning diversity - attracting students who would take advantage of the full range of opportunities here rather than focus narrowly in one specific discipline. Demographic and marketing studies should help to understand how students select the colleges to which they apply and to discover, if possible, why students who should think of MIT do not apply. We used a new leaflet, Liberal Education at MIT, to attract a better mix of students. But this year we had a larger number than usual of students who filed preliminary applications but not the final application. Interestingly, this year's cancellation study indicated a shift in our competition from Harvard to Stanford, but generally we share students in common with the Ivy schools.

It is our good fortune to have, as the new Director of Admissions, Michael C. Behnke, formerly Dean of Admission and Financial Aid at Tufts.

This year of transition has been one of the most exciting of my career here and I wish to thank the staff and the support staff for their dedication. They are, as a group, and individually the finest professional team one could hope to work with. I should also like to express my thanks to a supportive faculty who, more than ever, made us feel their confidence in our operation by volunteering their services regularly, and to Dr. Paul E. Gray and especially Constantine B. Simonides for the encouragement and understanding even when the numbers seemed to grow beyond the estimates set for enrollment. The future looks bright.

JULIA C. MCLELLAN
Alumni/ae totaling 1,568 served as Educational Counselors this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, and 48 foreign countries. This group included 216 women and 63 minorities (45 blacks, 10 Puerto Ricans, and 8 Mexican-Americans). The Educational Counselors represented MIT at 175 local College Fair programs; they conducted 5,897 admissions interviews and held countless conversations with prospective MIT students and with local school personnel. A record number of 95.8 percent (98.3 percent within the U.S.) of all applicants 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 251 students, representing approximately 125 different geographic areas (including 15 foreign countries), participated in this program run by the Educational Council Office.

Another program supported by the EC office was the AMITA High School Visiting Program. Marti Ward served as Administrator for this program for the second year, and coordinated the efforts of 139 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to visit 61 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. The program was extremely well received.
Personnel Office

The reports which follow highlight the past year in the sections that comprise the Personnel Office.

There has been a major emphasis this year on recruiting to attract applicants for support staff positions. The pool has decreased considerably, and new strategies are needed to increase the applicant pool.

The Internal Revenue Service and the United States Congress introduced a number of changes which impacted on benefit programs available to the community.

Reduced staffing combined with turnover placed a heavy burden on the staff in meeting the needs of the community. I, as Director, wish to thank the staff for their hard work and good humor.

A number of staffing changes occurred this year. Susan P. Gaskell was appointed as Manager of Services and Employment. Kim Bonfiglioli and Oveta Perry were appointed as Personnel Officers, Ms. Bonfiglioli to replace Ms. Gaskell and Ms. Perry to replace L. Muriel Birchette. Ms. Birchette and Anne Quill left MIT to pursue careers in industry. Ornah Becker joined the Benefits Office to work on special projects. Patricia Williams left the Personnel Office for a new position as Program Administrator in Applied Biological Sciences.

JOAN F. RICE

PERSONNEL DEVELOPMENT

A total of 5,000 employees participated in Personnel sponsored programs including in-house training and development opportunities; 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. Nine new programs were added in the training area addressing an assortment of job-related and career-related topics. Talks were presented by six faculty members in Perspectives, a series sponsored in conjunction with the Provost's Office and the Sloan School of Management.

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

Wage and Salary Administration

The Compensation Office continued its work to provide fair and equitable salary administration across the Institute during the annual review, and in studies of individual salary 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 reviews of Faculty, Support Staff, 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 for the appropriate marketplace, the Institute's economic outlook, and the relationship of the Institute's salary structure to these conditions. Participation in approximately 35 salary surveys during the year, and particularly in the MIT Faculty Salary Survey, the R & D Survey, and MIT's Administrative Survey, enables us to assess the Institute's position to these appropriate markets, and to make informed recommendations to the Executive Committee for adjustments to the Institute's existing salary structures and pay ranges.

Twenty-five universities participated in MIT's 1984 nationwide Faculty Salary Survey. For each of MIT's three faculty ranks, the Institute's average salaries exceeded the overall averages for the 25 universities. Special emphasis as selected ranks in the schools of Engineering, Management, and Science during this
The year's Faculty review should help to maintain the Institute's market position in the coming year. Refinements in programs in our tabulation of the survey data has provided participants with information displayed by individual school, and by professorial and institutional rankings. These improvements also provided more detailed information to our Deans prior to the Faculty Salary Review.

A total of 143 requests for reclassification on the Administrative Staff were received during the year: 46 descriptions received in connection with the ongoing process of classifying those reappointed from Exempt; 42 requests to assess newly created positions on the Administrative Staff; 21 promitional requests for individuals moving from Support Staff, and one from Service Staff; and 33 requests to reevaluate existing Administrative Staff positions and their salary ranges. In order to review so many requests in a way that assures a sense of equity across the Institute, we have developed a series of organization charts which display structures not only of departments, but of organizational areas. These have been a useful aid to Senior Officers in giving an overview of the departments and groups that report to them. The processing of individual requests has been enhanced this spring by the use of an IBM Personal Computer. The summer months should provide the time to complete the several requests which remain outstanding, so that by fall, virtually all incumbents on the Administrative Staff should be aware of the salary range of their position. We also plan extensive work to simplify the collection of and access to the sizeable data base which is associated with the Administrative Staff Salary Administration Program.

Salaries paid to members of the Support Staff continue to compare favorably to the local market of major Boston area employers. Salary ranges, and the position standards developed several years ago by the Working Group on Office/Clerical Issues, continue to be useful, fair, and workable guidelines for reaching equitable decisions regarding individual support staff positions, and in particular for assessing requests for promotion with the Support Staff. The position standards contribute substantially to the use of all ranges within the Support Staff structure.

Benefits Administration

In January MIT introduced the Flexible Reimbursement Account Program (FRAP), a tax-effective method of paying for dependent care expenses and/or unreimbursed medical or dental expenses. Nearly 1,000 employees enrolled in the plan. At the same time the Institute made significant improvements in the Retirement Plan for Staff Members (RPSM), the plan that covers faculty, academic, administrative, and research staff. One major change was that as of January 1, 1985, member contributions to the RPSM became tax-deferred.

The Premium Payment Plan, which tax-shelters employee contributions for health and life insurance, was revised to meet more stringent IRS regulations. The health insurance open enrollment period is being shifted from May to November, with changes to be effective each January 1, to coordinate with FRAP, Premium Payment Plan, and TDA enrollment cycles.

The Compensation Office developed a retirement handbook to be used in retirement planning, with distribution planned for FY 86. The Benefits Editorial Committee continued its work of revising and issuing the Summary Plan Descriptions for each benefit plan.

The Compensation Office has completed and tested the benefits segment of the personnel database, and is now planning the initial data entry phase. When completed, the database will sharply reduce the time currently needed to research employee inquiries, and will also make possible more sophisticated analysis of enrollment and usage of the 23 benefit plans currently offered.

We also developed more efficient administrative procedures for the Children's Scholarship Program, including design and implementation of a new database. The revised system will help the Compensation Office respond quickly to rapidly changing tax law.

During the past year the Compensation Office conducted 82 workshop sessions on benefits for current employees, including retirement planning seminars, tax deferred annuity workshops, and workshops introducing FRAP and the RPSM improvements. We also held 116 orientation sessions for new faculty, academic, research, administrative, support, and service staff.

KERRY B. WILSON

FACULTY AND STAFF INFORMATION SERVICES

The primary accomplishments were the final implementation of the Applicant Flow and Benefits portions of the Personnel database, as well as the implementation of major structural changes and modification changes to the database files. These accomplishments bring to a close the implementation phase of the Personnel database, begun in 1980, and position us for a new era in personnel information management: personnel information as product for distribution to other administrative areas within the Institute.
With the introduction of a new and more secured production environment, the Systems Section has been able to transfer control of executing report applications to other personnel users. Requests for new applications or modifications to existing applications will continue to be the responsibility of the Systems Section.

Reorganizational, maintenance and procedural changes were put into effect in an effort to accurately reflect all academic information with consistency and to have a common method of processing both academic and non-academic records.

ISAAC M. COLBERT

LABOR RELATIONS

The Institute and the Campus Police Association concluded a new two year labor/management Agreement in August, 1984 that provides for a six (6) percent wage increase in July, 1984, a four and one-half (4.5) percent wage increase in July, 1985, plus several trial policies that attempt to give Officers more time off the job without increased cost to the Department.

Negotiations are currently underway with the Service Employees' International Union, Local #254, (two (2) units); the Research, Development, and Technical Employees' Union; the Hotel, Restaurant, Institutional Employees' and Bartenders' Union, Local #26 (two (2) units); and the Independent Union of Plant Protection Employees, Local #14. The Director of Personnel, Joan F. Rice, is chief spokesperson for the two Service Employees negotiations, with the Manager of Labor Relations serving in a like capacity for the other four negotiations. All the Unions have their usual long lists of demands but they have uniformly put great emphasis on improvements in pension plan benefits. An early and equitable conclusion to these negotiations is being pursued mutually.

The labor grievances and arbitrations have remained at a stable level with the usual backlog of arbitrations testing the endurance of the staff. A number of the arbitrations are on critical contract issues such as bargaining unit work, expansion of the temporary assignment provision, and lay off rights. Mr. Michael J. Parr continues to manage the heavy work load associated with all aspects of the 2A classification procedures, grievances, and arbitrations in a capable manner.

The Office has continued its program of presenting labor relations seminars for departments and laboratories. The subjects of these sessions are the duties and responsibilities of managers for labor relations, application of discipline, absenteeism policy, general contract administration, the performance of bargaining unit work by non-bargaining unit personnel, etc. Plans have been made to continue this work in the next fiscal year, coordinating the program through Personnel Development.

JAMES J. FANDEL

PERSONNEL SERVICES AND EMPLOYMENT

Personnel Services

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, screen and refer candidates for positions, and work closely with supervisors and employees on organizational needs to improve the effectiveness of human resources. In addition, Personnel Officers have increased their participation in the development and presentation of training programs.

Employment Activity

A total of 1,205 positions were posted during the year, 26 percent more than the previous year. Personnel Officers interviewed 1,920 applicants, a seven percent increase in the number of interviews granted last year. Qualified applicants were referred to one or more supervisors generating 2,669 departmental interviews. Additionally, 8,823 resumes were received, reviewed and acknowledged by mail. From this applicant pool of 10,743, 955 were hired. In addition, 178 employees successfully transferred into new positions within the Institute.

SUSAN P. GASKELL
Quarter Century Club

The MIT Quarter Century Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Vice President in the Office of the President.

The membership of the Club totals approximately 1870, with each member having served the Institute for more than 25 years. The annual meeting, at which new members are inducted into the Club, takes place in the spring. Other annual functions include a picnic in the summer and a holiday gathering in December. The Club also provides administrative and logistical support to the Institute's annual charitable campaign and to its retirement dinner in June, as well as special functions when requested by the Administration. The Club also administers the MIT Activities Committee (MITAC) which organizes recreational and cultural activities for the employees. The Club provides services and space to a chapter of the American Association of Retired Persons Inc. (AARP), the purpose of the organization being to aid persons over 50 years of age in their social, physical, economic and intellectual needs.

An extensive travel program is organized for the alumni, retirees, and the Institute community offering approximately 100 departures to various destinations annually. Some of these include lectures or other educational aspects.

There are five officers and nine directors on the board. The staff of the Club consists of Ann P. Brazier, manager, and three assistants, M. Frances Daly, Nanci Drago and Diane Betz.

DANIEL H. GOULD
Secondary Technical Education Project

The Secondary Technical Education Project (STEP), which 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, has recently completed a year of change and refocus.

The energies of the STEP Ad Hoc Committee and project personnel centered on providing direct-services to students, faculty and parents at the Mario Umana High School of Science and Technology, in addition to guiding the planning effort of Dr. Robert Peterkin, Superintendent of Cambridge Public Schools, with respect to infusing computers into the curriculum.

Under the direction of the Ad Hoc Committee, Alan Dyson, the STEP Director, now spends 80 percent of his time with the Boston involvement (funded through Chapter 636 Massachusetts Desegregation) and 20 percent assisting with the development of the School of The Future (funded through MIT, President's Fund for Community Affairs).

STEP's focus in both Cambridge and Boston is to assist schools integrate computer-based technology into all phases of the curriculum, using the computer as a tool rather than computer as an object of study.

The focus at Mario Umana this year has been a planning effort aimed at providing each student with an opportunity to become comfortable using computer-based technology. The school now has a DEC PDP 11, used primarily to teach Basic and Pasqual, a Control Data Plato Lab used to upgrade the basic skills of poorly achieving students, an Apple IIe Lab used to introduce seventh and eighth graders to applications packages and in September, 1985, a fourth Lab, an IBM Micro Lab will be installed. The focus of this Lab will be to insure all Umana students graduate with a degree of comfort with computers.

The focus in Cambridge has been on planning with the Director's time equally divided between management issues and city-wide planning for the use of computers.

1984-1985 HIGHLIGHTS

Mario Umana High School

MIT Based Writing/Arts Program for the Gifted and Talented.

Computer/Curriculum Planning.

Technology Insights Program - Collaboration, STEP/MIT Museum/Masspep.

Cambridge Public Schools

Alan Dyson, STEP Director - Co-chair of City Wide Computer-based Planning Team.

Adviser to Managers of the School of the Future.

Dr. Myron Tribus/Alan Dyson - Host Series of Management Seminars for Public School Managers Using W. Edwards Demming Management Philosophy.

Al Shanker, President of United Federation of Teachers, at Request of Alan Dyson, Led an Educational Management Forum at MIT Focusing on Demning Philosophy.

ALAN DYSON

DOROTHY MAC DOUGALL
Committee on the Visual Arts

A presidentially appointed group composed of members of the faculty, administration, and student body, the Committee on the Visual Arts (CVA) oversees policy for an ambitious program in the visual arts which is administered by a professional staff. The CVA is charged with a broad spectrum of responsibilities: to foster and present, through its nationally recognized exhibition program, the most challenging contemporary art and design; to provide the MIT community and general public with educational activities which increase visual literacy and explain how the visual arts reflect ideas governing contemporary society; to enhance the quality of the Institute's visual environment and to encourage daily experience with original works of art through three publicly sited collections of contemporary art in all mediums; and to contribute to the cultural vitality of the region.

The CVA met four times during the 1984-85 academic year. The membership focused on the increased programmatic and budgetary responsibilities associated with a mid-year move to the new List Visual Arts Center within the Arts and Media Technology Facility. Following the goals established in the mission statement prepared during 1983-84, the range of interdisciplinary educational programs was broadened, with faculty from numerous departments playing a pivotal role as both planners and participants. In order to bolster external funding, ten proposals for 1985-86 initiatives were prepared and reviewed.

EXHIBITION PROGRAM

The 11 CVA exhibitions continued to focus on advanced contemporary visual expression in all mediums; the 1984-85 season, however, was marked by the mid-winter transfer of both offices and galleries to the new List Visual Arts Center. With nearly double previous exhibition space, the program could expand in scope and, in the new Reference Gallery, accommodate a stronger residency and performance component. Reviews appeared in publications such as The New York Times, The Wall Street Journal, The Boston Globe, and The Christian Science Monitor.

1984-85 Exhibition Schedule

Hayden Memorial Library Building:

List and Stratton Student Loan Collections, Hayden Gallery, August 31-September 20, 1984. The annual exhibition and lottery of approximately 260 prints and artist-designed contemporary posters included a recently acquired portfolio by David Salle and prints by Pat Steir, Jennifer Bartlett and Robert Zakanitch.

CVA Exhibition Poster Archives, Hayden Corridor Gallery, August 31-September 20, 1984. Exhibition posters from the last decade, including those acquired by the design department of the Museum of Modern Art, New York were made available for purchase.

Philip Guston: The Last Works, Hayden Gallery, October 13-November 25, 1984. This survey included four late oils and the last 35 works on paper from 1981, the cartoon style and anxious imagery of which influenced a great number of subsequent painters, particularly those living in Boston. The exhibition was selected by the three major newspapers in the region as the best of the year.

Local Visions IV: Portraits, Hayden Corridor Gallery, October 13-November 25, 1984. Work by seven area artists, including traditional pastels, altered prints, collaged paintings, and experimental photography represented different attitudes toward portraiture.

STILLDANCE: a recollection, Hayden Gallery, December 15-January 27, 1985. This collaboration between choreographer Beth Soll and photographer J. C. Hotchkiss used photocollage, ambient music, and architectural structures to present a narrative based on the synthesis of dance and photography. The sound and voice accompaniment was by composer David Moss. (Funded in part by Dance Projects, Boston)

On the Wall/On the Air: Artists Make Noise, Hayden Corridor Gallery, December 15-January 27, 1985. Guest-curated by Kevin Concannon, this exhibition included musical documents and notations for audioworks by 20 contemporary American artists and composers. Related radio programs were produced for WGBH and WMBR. Brochure published. (Funded in part by the Massachusetts Council on the Arts and Humanities)
List Visual Arts Center:

Giacometti to Johns: Selections from the Albert and Vera List Family Collection, Hayden Gallery, March 1-April 27, 1985. To inaugurate the largest of the new exhibition spaces, approximately 40 major works ranging from a 1924 Arp painting to a 1983 mixed-media sculpture were selected to represent the range, quality, and adventurousness of the List’s personal collection of recent art. Dedicatory brochure and a checklist of the exhibition published.

Stuart Sherman: Chekhov Plus, Reference Gallery, March 1-March 31, 1985. This New York performance artist showed four sculptures, drawings for and tapes of previous theater events, and films. Over the course of the month, he created the set for and produced a 12 minute evocation of the complete works of the proto-modernist Russian dramatist. This visual theater piece will be performed in New York and Europe during the summer months. (With in-kind support from MIT’s Film/Video Section and Educational Video Resources)

Jacques Lipchitz: Sculptor and Collector, Sculpture Archives Gallery, March 1-June 9, 1985. Organized by Jeanne Wasserman, emeritus curator of modern sculpture at the Fogg Art Museum, this exhibition is the first in a series to illustrate the development of 20th century sculpture through the work of artists represented in the MIT Permanent Collection. Sculptures and drawings in many mediums from all phases in the artist’s career, together with selected objects from ancient and non-western cultures which he had collected, were included. Illustrated brochure published. (Supported in part by the National Endowment for the Arts)

Thomas Kovachevich: Lessons and Characters, Reference Gallery, April 4-30, 1985. The residency project of this artist and family medicine specialist included performances, interdisciplinary collaborations, and dialogues with MIT faculty members. An accompanying exhibition was organized of his paper sculptures which react to varying atmospheric conditions, together with the paintings based on experiences with these performing paper forms.


Difference: On Representation and Sexuality, Reference Gallery, May 11-June 23, 1985. Organized by the New Museum of Contemporary Art in New York, the work of 16 artists from North America and Britain explored, through photography and video, the cultural formation of notations of sexuality, gender, and representation. (Supported by the Jessie B. Cox Charitable Trust Fund and the Massachusetts Council on the Arts and Humanities through the New England Foundation on the Arts)

ACQUISITIONS

The permanent collection grew through both gifts and purchases. Among major additions were a portfolio of lithographs by the late Philip Guston, James Turrell's DEEP SKY portfolio of aquatints and a large screenprint by Richard Estes.

Twenty-six works were added to the List Student Loan Program, including portfolios by Lois Lane and Edda Renouf. A portfolio of 15 framed lithographs by Joan Miro was added to the Catherine N. Stratton Student Loan Collection, as were works by Gabor Peterdi and Ben Shahn.

EXTENDED LOANS TO THE COLLECTION

(See 1983-84 Annual Report)

CONSERVATION

Restorative work was performed by Steven Tatti, conservator, on Isaac Witkin's ANGOLA and Henry Moore's THREE PIECE RECLINING FIGURE, DRAPED.

The following paintings were treated by the Center for Conservation Studies, Fogg Art Museum, Harvard University: Joyce Kozloff, THREE FACADES; Katherine Porter, LA CANOVA; Richard Smith, REVOLVAL I; Ernest Trova, STUDY: FALLING MAN and Victor Vasarely, SURKE.

A large number of works were reframed by Old Cambridge Co., Boston.
LOANS FROM MIT'S PERMANENT COLLECTION TO OTHER INSTITUTIONS


EDUCATIONAL PROGRAMS

A wide variety of educational activities was designed to broaden the participant's awareness of the cultural and art historical issues suggested by the exhibitions and permanent collection.

Informational Wall Text

Each exhibition was accompanied by a one or two page statement by the curatorial staff which provided the uninitiated viewer with an introduction to the work on view. For the inaugural exhibition of works from the collection of Albert and Vera List, extensive labels were prepared about each work in the exhibition, focusing on the artist's formal and thematic concerns in the creation of that particular piece.

Talks, Tours and Lectures

Gallery talks and tours of the collection were arranged for a number of visiting and MIT groups, including regional school and community groups. For Philip Guston: The Last Works, a public dialogue was held with a poet, professor, critic and emerging painter, each of whom knew the painter well; a film was shown covering the artist's life and work. STILL DANCE: a recollection was accompanied by a dialogue between the dancer, photographer, and composer who collaborated on this installation. A series of radio programs on WMBR hosted by Kevin Concannon, guest curator of On the Wall/On the Air: Artists Make Noise, documented artists' use of audio; another program on WGBH provided a special preview to the works in the series. Two artists in the series, Christian Marclay and Bill Buchen, performed live at a local nightclub in conjunction with the exhibition. CVA curator Katy Kline gave a public gallery talk on Robert Moskowitz: Recent Paintings/Judith Shea: Recent Sculpture and assistant curator Dana Friis-Hansen led a tour of Difference: On Representation and Sexuality.

Artists in Residence

Designed to function as a hybrid of studio, laboratory, and staging area, the Reference Gallery allows the audience to observe artists pursuing their artistic research and to discuss the development of a particular work; emphasis is placed on the process rather than product. During the residency of Stuart Sherman in March, the artist collaborated with Robert Scanlan, Director of the MIT Dramashop on two directing workshops, presented and discussed his films, and produced his latest theater work, Chekhov. Thomas Kovachevich's Lessons and Characters served as the occasion for a series of diverse conversations between the artist and faculty from the fields of medicine, psychology, anthropology and archeology, chemistry, dance and physics.

Collections Information and Access

Stephen LeBlanc, a senior in electrical engineering and computer science, began to develop as part of his senior thesis a sophisticated database and querying program to identify works in the permanent collection. Once completed, students will be able to scan the entire collection and identify pieces based on materials, style, artist, subject, size, and period. The database will be accessible to the community through Project Athena.

CVA STAFF
BORIS MACASANIK
Transition is the most appropriate word to characterize the Council during its fourteenth year. Perhaps the most obvious transition was our move to the newly completed Arts and Media Technology building. Now that the fund-raising for this building has been completed, we have begun to develop new areas of growth for the Council itself, and have shifted our emphasis from service and advocacy to more active programming. During the past six months, we have initiated a sizeable sponsorship program whereby the Council serves as a catalyst and fiscal agent for interdisciplinary, collaborative projects in the arts at MIT.

Arts Programming

The essential function of the Council is to support students, artists, and their work. The core of this support is the Council's Grants Program. Our efforts in this area have been greatly appreciated, both by the grant recipients and by members of the MIT community who have participated or benefited from this support. Some comments from Council grantees clearly demonstrate this. A faculty member who came to the Council staff to organize a series of readings and workshops by nationally-recognized women writers wrote: "Our committee's plans reflected our inexperience; we were unrealistic and wildly impractical. You carefully and thoroughly explained grant application procedures. You outlined a series of lecture/readings which you thought we could manage. You showed, by example, the importance of having clear goals. [The series] began with a public reading by poet Gwendolyn Brooks. Two thousand people ... crowded into the auditorium; when The Boston Globe carried an article about Brooks, our series was launched."

Ron Soltz '87 writes in his grant report, "It is quite a privilege to attend a first rate science and engineering college and also to study at the Berklee College of Music with a premiere jazz instructor." In the final report by grant recipient Michael Teng '88, he writes "Grants like yours make it possible for musicians like me to pursue their dreams."

Through the efforts of the Grants Committee, chaired by Bradford M. Endicott '49, we were able to support 16 performances, 30 student-initiated projects, 12 exhibitions, 10 lecture/workshops, and two national tours of MIT student arts groups. A residency by performance artist Stuart Sherman was one of many Council-supported projects to receive press coverage. The Boston Globe referred to Sherman as "a zany original humor...a trenchant wit." Sherman's residency and performance stimulated extensive student and faculty participation--setting a model for many other grantees.

The Grants Committee is perhaps most effective in its role as a catalyst. One example was a controversial grant of $2,000 allocated in support of private instrumental music study for talented MIT students. The Committee felt strongly that this type of project should be funded annually by an academic department and not by the Council. Members of the grants committee met with the Dean of Humanities and Social Science and were able to secure a commitment of matching funds of $2,000 for the 1985/6 academic year, and full funding thereafter.

To respond more immediately to requests for support, we increased the number of Grants Committee review meetings from three to four. Committee members reviewed 60 proposals requesting a total of $114,000. From these, 77 percent, or 46 proposals requesting $70,319, were granted. These funds were matched by $180,000, obtained through the efforts of the Council staff. A detailed report from the Grants Committee is available. The number of proposals submitted to the Council, including officer's grants, remained the same as last year--74.

Staff members continue to provide advice about fund-raising and proposal writing to more than 20 faculty and staff each week, and members of the Grants Committee volunteer their time and resources to assist with individual projects.

To encourage more student participation in the arts, Program Officer Alison Shafer organized a community-wide competition to redesign the guidelines brochure for the grants program. At the request of MIT Medical Director Melvin Rodman, Ms. Shafer also worked with a student intern to select thirty framed artist-designed posters for the patient waiting areas of the Medical Department.

For the fifth consecutive year, Council efforts and support have ensured the continued participation in the Boston Museum of Fine Arts University Membership Program. Susie Lee '88 and Oren Michels '85 wrote to the program sponsor, Council member Solomon Manber '48, "We're proud to tell you that more MIT students visit the Museum than students from any other college in the Boston and Cambridge areas, other
than Northeastern." Ms. Shafer and two student volunteers assisted with the planning of an annual Open House at the Museum this April, when MIT was represented by the Logarithms, and eight undergraduate students performing individual piano recitals in the rotunda to a large and appreciative audience.

Through the support of the Abramowitz Lecture Fund, the Council invited Erick Hawkins, hailed as one of the "pioneer revolutionaries of modern dance," to be in residence at MIT in late October. Assistant Director Richard MacMillan produced the Company's performance and lecture/demonstration in the Kresge theatres. A Master Class offered to individuals in the MIT community was filled to capacity. Favorably received in local newspapers, the Company's residency is most notable because of the student involvement it fostered.

Council Secretary Roy Lamson coordinated the Student Art Awards Committee. The Laya and Jerome B. Wiesner Student Art Awards of $1,000 each were presented to graduating senior Patrick Tacon, for his contributions to the musical life at MIT, and to Marc DiNardo, graduate student in Aeronautics and Astronautics, for service in the theatrical arts, particularly Dramashop. The Louis Sudler Prize in the Arts was awarded to Oren Michels, a graduating senior in Electrical Engineering for his outstanding achievements in theatre. The Gyorgy Kepes Fellowship Prize Committee, chaired by Council member Angus MacDonald '46, reviewed nominations for its $2,000 award, and selected Keiko Prince, former Fellow of the Center for Advanced Visual Studies, as recipient.

**Membership**

Eight new members accepted three-year terms in July 1985. These include John Karmasin, Jr. '47, Alex Dreyfoos, Jr. '54, Kitty Carlisle Hart, Frances Balter, Robert B. Semple '32, Morton M. Davis '54, Alwin Nikolais, and Raymond D. Nasher. The Council now has 95 members. Fifty-four of our Council members are MIT alumni. Our efforts again this year have been to identify members who demonstrate scholarship, creativity, and distinguished service in a variety of art disciplines.

**Development Efforts**

During each year since 1982, the Council has raised 100 percent of its budget from Council members and friends. This year, 62 of our members provided direct support to the Council's operations, with an average gift of $2,800. This support was supplemented by 47 gifts from friends of the Council, with an average of $964. These figures represent a $300 increase over last year's average gift in both categories.

Contributions from friends of the Council support about 20-25 percent of Council activities annually. Although the Council is in sound financial shape, we cannot afford to be complacent. Plans are underway to identify new sources of support and to broaden the base of this support. The Council's revitalized Development Committee organized by Mr. MacMillan and enthusiastically chaired by Gregory Smith '30, has designed new initiatives for locating, researching and visiting alumni and friends who have demonstrated an interest in MIT's commitment to the arts.

During the past seven years, Council members have contributed, or assisted with the solicitations for, almost $8 million of the capital expenses for the Arts and Media Technology building. Consequently, the Council's own programs and operations have grown in a far more conservative but steady manner. With completion of funding for this building, we were able this year to develop a new area of program initiative. The staff worked in collaboration with numerous individuals and groups at MIT to coordinate grant requests for special projects in the arts. These include: a collaboration with the Wooster Group, an experimental theatre group from New York City, and Peter Sellers, Artistic Director of the American National Theatre; a four-month residency for two internationally-recognized artists, Diamanda Galas and Richard Zvonar, with the MIT Film/Video program; and a graduate scholarship in holography. The total support for these special projects, $71,125, came primarily from government agencies.

Council members have regularly contributed works of art to the MIT Permanent Collection, the List Student Loan Program, and the Catherine N. Stratton Student Loan Collection. This year, Vera List and her family contributed 25 prints and James R. Killian, Jr. contributed two prints.

**Information And Publications**

Mr. MacMillan wrote and edited six issues of our calendar/newsletter, with Cynthia Woolley, Secretary, coordinating the calendar of events. This was distributed to a mailing list of 7,000. Ms. Shafer produced a new version of the Grants Guidelines Brochure, as well as a sampler of press clippings about MIT artists and arts activities, MIT Arts in the News. We distributed twenty thousand copies in the September 19 edition of Tech Talk, and 3,000 were distributed by the Educational Council and the Alumni Association.

One of our major accomplishments this year was the completion of a brochure for high school students and Educational Counselors, The Arts at MIT. Funded by Council member Kenneth Germeshausen '31, this brochure gave us the opportunity to identify and describe, for the first time, all MIT resources in the
arts for undergraduates—including courses, facilities, faculty, scholarships and awards, and local attractions. Based on figures provided by the Admissions Office, we printed 40,000 copies for a three-year period. The popularity and use of this brochure has already exceeded our expectations, and we now hope to reprint the brochure within two years.

In response to increasing telephone calls requesting information about arts events at MIT, Ms. Shafer established the Arts Hotline, 253-ARTS. Updated weekly, the service is a recorded list of arts events taking place at MIT.

Annual Meeting

Coinciding with the dedication of the Albert and Vera List Visual Arts Center, the Annual Meeting of the Council for the Arts took place on March 1 and 2. A dinner for Council members, students, and other invited guests honored the recipient of the Gyorgy Kepes Fellowship Prize. Nan Freeman, arts educator from Wellesley College, gave a brief presentation highlighting trends in contemporary art.

The formal dedication ceremonies in honor of Council member Vera List and her husband, Albert List, were preceded by an inspired address by Marcia Tucker, director of the New Museum of Contemporary Art in New York. Architect I.M. Pei '40, recipient of this year's McDermott Award, spoke eloquently about his work to an assembly of students, faculty, and Council members earlier in the day. Paul Goldberger, architectural critic for The New York Times, addressed a luncheon gathering given in Mr. Pei's honor.

Personnel

Following the resignation of Barbara Allen, Richard MacMillan joined the staff as Assistant Director. Alison Shafer was promoted to Program Officer. Cynthia Woolley, Senior Secretary, joined the staff in August. We were fortunate to have two interns, Phyllis Muto and Misty Burrage, assist us with special projects. Since I announced my resignation, I have been working with a Search Committee to identify a new Executive Director.

DEBORAH A. HOOVER
Vice President for Financial Operations

Fiscal 1985 is the second consecutive year that we have had a modest surplus after two years of small deficits. The fact that the year ended with a favorable balance of income over expenses reflects the economic climate and the considerable efforts of faculty and staff in cost control.

Despite the results of the last few years, we continue to face critical financial issues that can affect our future. Among these issues are the following:

- Spending most unrestricted gifts, grants and bequests for current operations rather than to increase endowment.
- Reliance on sponsored research for over two-thirds of operating revenues and the relatively small portion of unrestricted or discretionary funds in the operating budget.
- Small size of the endowment relative to the size of instructional and research programs.

The solution to the major financial problems faced by MIT is evident: we need to increase our endowment significantly. While we are a strong and vibrant institution with a record of extraordinary achievement, we have a critical need for more endowment to assure our future.

The amount of endowment income that is available for spending depends primarily on the size of the endowment. Increased income from a larger endowment will help solve many of our financial issues. It will help to meet the increased cost of student aid and the expenses related to instructional and unsponsored research. It will help in the intense competition for outstanding faculty and staff. It will provide a more stable institutional base for faculty salary support. Finally, it will permit us to add unrestricted gifts to endowment rather than use them for current operations.

While endowment income has shown significant growth over the years, it has declined in proportion to the more rapid growth of operations. Since 1978, the market value of endowment and similar funds, after the spending of income, has increased at an average compounded rate of almost 13 percent per year. Despite this growth, investment income for operations has declined relative to the size of our annual operations.

Among those major research universities with which we compare, our endowment is the smallest in relation to operating expenses. Among all colleges and universities, MIT ranked seventh in a recent survey in terms of the size of its endowment, fell to nineteenth place in terms of its endowment per student, and to thirty-third place in terms of endowment per faculty member. The reason can be traced to our continued rapid growth relative to other universities, the high expenses caused by the technology-based quality of our instruction and research, and the relatively few decades we have had to build our endowment.

We are beginning a major initiative to significantly increase endowment. The initiative will require extra effort from our faculty and staff and the increased commitment of our Corporation members and other volunteers. This effort will strive to bring the Institute to a new level of financial strength and academic achievement.

The reports that follow highlight the activities in each of the four major areas of financial operations. This report is my first as Vice President. I would be remiss if I did not thank the Department Heads and their staffs for making this a very memorable year for me personally. Their continual willingness to spend time in educating me on the complicated aspects of Institute finance is very much appreciated. It makes me realize that all of our high quality teaching is not done by the faculty alone. I would also like to thank Stuart Cowen for his continuing advice and guidance to me throughout the year. To use the faculty analogy, Stu has been my Institute Professor.

JAMES J. CULLITON
Office of the Comptroller

In the fall of 1984, the Institute renegotiated automobile rental Corporate Rates with Avis and Hertz and negotiated Corporate Rates with several local hotels allowing for favorable rates for visitors to the Institute.

In November 1984, the Accounts Payable/Purchasing System was transferred from the Joint Computer Facility to its own Digital Equipment Corporation VAX 780 located in W-91. In April 1985, the VAX was upgraded to a 785. Accounts Payable is now in the process of planning expansion of this system to other parts of the Institute.

The Account Reporting System is now in the process of being transferred and rewritten from an IBM 148 to a VAX 785. In March 1985, new accounting statements were produced using the Xerox 9700 printer. This change has resulted in more timely reporting of costs to the Institute community in an improved format and at a significant cost reduction to the Institute.

As of March 1, 1985, the Cashier's Office implemented a new system for recording the Institute receipts and petty cash disbursements. The system consists of a number of IBM personal computers networked together which allow cash transactions to be recorded on the Institute's books as a result of the data entered by the cashiers. It also generates receipts to depositors as a by-product.

In July 1985, the Chart of Accounts Interactive System will be in place on the VAX 785.

During the past year, a considerable effort was devoted to the implementation of a new Staff Pension Accounting System. The original system developed in 1967 was in need of upgrading because of the advances in computer technology and, most important, significant changes to the Pension Plan which allowed member contributions to be tax sheltered effective January 1, 1985.

During this past year, we began and completed the implementation of the Flexible Reimbursement Account Program. This modification caused a delay in the schedule involving the implementation of the new Student/Voucher Payroll System which has resumed and is now scheduled for implementation within the next two months. When completed, this segment will be merged with, and become part of, the single weekly payroll processing plan. The Staff Appointment conversion, which is the final phase in the overall payroll conversion project, was only briefly reviewed and its scheduled resources redirected to the Student/Voucher project in the interest of completing that task as quickly as possible.

The Lincoln Fiscal Office continued its accounting system conversion to an interactive operating system utilizing an IBM System/38 and completed programming a new payroll system. A review of other systems and control programs was begun and will continue during the coming year.

The role of the Audit Division is to verify that management policies and procedures are being properly implemented, that internal controls are being maintained, and that assets are safeguarded. This is accomplished through audits of: Departments and functions, ascertaining whether units are operating according to Institute guidelines and within prescribed contractual and budgetary limitations; Computer based systems, focusing on the adequacy of specific application controls, data security features and backup and disaster-recovery procedures; Administrative units, determining whether internal control procedures are adequate and functioning as intended; and Inventories, receivables, and cash (or equivalents), evaluating the control and authorized use of the Institute's assets and also determining valuations for annual statement presentations. These reviews and tests are coordinated with the Institute's Certified Public Accountant firm of Coopers & Lybrand and the Institute's federal cognizant audit agency, the Defense Contract Audit Agency. Said examinations enable the Audit Division to identify errors and monitor resolutions; to offer recommendations for improvements; and to verify implementation of proposed recommendations or alternative procedures.

Personnel Changes

The following staff changes occurred during the past year: In August 1984, Scott T. Thornhill joined the Lincoln Fiscal Office in the capacity of Staff Accountant. In September 1984, David E. Burnett was promoted to Assistant Accounting Officer; Debra E. Cobb was promoted to Senior Staff Accountant; Carol J. Gleason was promoted to Senior Staff Accountant; and Candice Y. Tang joined the Audit Division in the capacity of Auditor. In November 1984, Robert M. Slausis was promoted to Assistant Accounting Officer. In December 1984, David Mark Sprague joined the Comptroller's Accounting Office in the capacity of Applications Programmer. In January 1985, Glenn H. Myers joined the Comptroller's Accounting Office in the capacity of Applications Programmer; and Charles A. Shaw joined the Audit Division in the capacity of Auditor. In February 1985, Marcia C. Clifford joined the Audit Division in the capacity of Auditor. In
May 1985, Pamela W. Seeler joined the Audit Division in the capacity of Auditor. In June 1985, Anastasia J. Janus was appointed Staff Accountant; and Pauline J. Reynolds retired after 27 years of service to the Institute. The department was saddened by the deaths of James F. Brady who faithfully served the Institute for 25 years and Edward P. Donnelly who faithfully served the Institute for 11 years.

PHILIP J. KEOHAN
Fiscal year 1985 ended on a favorable note with a surplus of $1,512,000, the second surplus in four years and the sixth in the last decade. The favorable outcome reflects the considerable efforts of faculty and staff in cost control combined with a moderate increase in inflation (about 4.8 percent for US urban workers).

Total operating expenses reached $717,187,000 -- up 8.9 percent from the previous year. Total operating revenues and funds used were $710,345,000 -- an increase of 9.0 percent over 1983-84. The difference between these two numbers (referred to as the "operating gap" or the "additional need for unrestricted revenues and funds") provides a good measure of the Institute's progress in dealing with financial constraints over the last decade. In fiscal year 1976 the "operating gap" was $6,493,000 while in fiscal year 1985 it was $6,842,000. As a percentage of total operations the operating gap has declined from 2.4 percent in fiscal year 1976 to just under one percent in fiscal year 1985. This statistic, combined with a knowledge of the new initiatives and ventures undertaken by MIT over the last decade, is a considerable tribute to the strength of the MIT faculty and their ability to draw support for their efforts from a broad spectrum of sources, both public and private.

To meet the operating gap there are unrestricted revenues from gifts, grants, bequests, patents, and the use of facilities allowances from sponsored research contracts. In fiscal year 1985 these sources totaled $8,354,000. To fund the operating gap required $6,842,000 of these sources, leaving a surplus of $1,512,000.

In fiscal year 1985 the Budget Office began the installation of a "local area network" to link together individual computer workstations for access to the office's database. The system, which will become fully operational in the next fiscal year, should improve our ability to perform special financial analyses and to help the MIT community in their budgeting work.

PERSONNEL

During the year Catherine Ormond was promoted to the position of Senior Budget Officer in the Fiscal Planning and Budget Office. In addition Mary E. Gibson was promoted to Budget Officer, and Carol A. Teixeira to Administrative Assistant. Ebba V. Walsh retired after serving faithfully for over thirteen years as a Senior Secretary and was replaced by Mary E. Garrity who transferred from another position at MIT. We were fortunate to have Ugebai M. Poweigha and John R. Mason join us during the year as Assistant Budget Officers and Deborah L. Fairchild as Budget Officer.

JOHN A. CURRIE
Office of Registration and Student Financial Services

BURSAR'S OFFICE

Student Accounts

Total student account billings for the year were $113,605,509, an increase of 9 percent from a year ago. Income from late payment fees totalled $66,674 while the income from finance charges totalled $185,537.

In the spring of 1984, new collection procedures were established to deal with twelve month delinquent accounts. As a result of those efforts, our June 1985 twelve month delinquent accounts balance was $31,989, a 62 percent decrease from June 1984.

Student Loans

Student loans receivable amounted to $36.4 million at the close of the fiscal year. These notes are funded by $10,391,000 of MIT loan funds established by friends and alumni of the Institute, $18,419,830 of Federal funds in support of the National Direct Student Loan (NDSL) Program, $214,000 in funds borrowed from the Federal government to support a portion of our contribution to the NDSL Program, $2,324,765 borrowed from the Student Loan Marketing Association (SLMA), $3,100,000 borrowed from a local bank, and $1,945,405 from Institute investments.

MIT's Parent Loan Program, established in 1977 to assist parents of students receiving little or no financial aid, continues slowly to grow. There are now 620 active accounts with an outstanding balance of $3,676,000. A total of $2,900,000 was disbursed during the year and principal collected totaled $2,358,000. This program is fully funded by a loan from the SLMA.

Student Loan Collection

A comparison of our collection results in June 1984 and June 1985 shows that total loans receivable increased 6.3 percent to $36,424,857 and loans in active repayment status rose 4.9 percent to $20,918,026. Despite these increases, the delinquency rate as a percent of active loans decreased by 7.7 percent and the total number of delinquent accounts remained constant at 1,627.

This further improvement in our collection efforts was achieved by resolving more early delinquencies (at the 90 days to one year past due level). This approach allowed us more time to work with borrowers who need personal attention at an early stage, before their repayment problems are allowed to age.

The default rate on National Direct Student Loans (NDSL) decreased from 2.3 percent in 1983 to 1.6 percent in 1984; the default rate on Federal Insured Student Loans (FISL) decreased from 5.7 percent in 1983 to 2.4 percent in 1984. These are among the lowest default rates in the country. The 1984 national default rates are 9.0 percent for NDSL and 16.3 percent for FISL.

Collection of international student loans was expanded to include accounts that had been written off because of foreign political situations or currency exchange problems. Many of these debts have been repaid in full or otherwise settled. As a result of our collection efforts, our recoverability from more recent borrowers in those countries has also increased dramatically.

Systems Integration and Control

Electronic data processing for the student accounts system was transferred to the MITVMC machine, which yielded quicker response time and added file storage capacity. Our cash receipt system is now on the computer, resulting in more timely updating of student accounts. We have started to develop an electronic data processing system to apply to the sponsored billing function.

The student loan system was modified to include daily (rather than weekly) updating of files, on-line access to biographical and financial records, data entry through direct keying (rather than log sheets for keypunch processing), the creation of a transaction file, and the capacity to record collection memos.
Staff Notes

Arthur R. Wagman resigned his position as Bursar in December to enter private business. He was succeeded in March by Shirley M. Picardi, '72, who had served as Secretary of the MIT Alumni Association since 1981.

Cynthia K. Wagner, Assistant to the Bursar-Loan Collection, resigned in April to accept a position in another state. Judith Syatt Levy, Assistant to the Bursar-Loan Collection, also resigned in June to relocate to another state.

REGISTRAR'S OFFICE

Enrollment

In 1984-85 student enrollment was 9,626, compared with 9,577 in 1983-84. This total was comprised of 4,536 undergraduates (compared with 4,602 the previous year), and 5,090 graduate students (compared with 4,975 the previous year). Graduate students who entered MIT last year held degrees from 386 colleges and universities, American and foreign. The international student population was 2,145, representing 13 percent of the undergraduate and 31 percent of the graduate population. These students were citizens of 97 countries.

In 1984-85, there were 2,211 women students (1,157 undergraduate and 1,054 graduate) at the Institute, compared with 2,066 (1,090 undergraduate and 976 graduate) in 1983-84. In September 1984, 309 first-year women entered MIT, representing 29 percent of the entering class.

In 1984-85, there were 1,189 minority* students (1,021 undergraduate and 168 graduate) at the Institute, compared with 1,107 (914 undergraduate and 193 graduate) in 1983-84. The first-year class entering in September 1984 included 289 minority students representing 27 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1984-85 included 1,131 bachelor's degrees, 1,045 master's degrees, 56 engineer's degrees, 447 doctoral degrees—a total of 2,679.

Tabular Presentation

Most of the above 1984-85 figures are taken from the several tables which follow. These tables, together with others dealing primarily with historical comparisons and demographic data, comprise the annual Registrar's Report, separately published and available upon request.

Staff Notes

Eleanor J. Miller, Supervisor of Registration, and Dorothy G. Staknis, Administrative Assistant, retired this year.

John T. Blake, Technical Supervisor for our Computer System transferred from Administrative Systems.

*Minority students include 315 Blacks (non-Hispanic), 19 native Americans, 200 Hispanics, and 655 Asian Americans.

STUDENT FINANCIAL AID OFFICE

Responding characteristically to a slowdown in the rate of cost inflation, the aggregate need of undergraduate students also rose by a smaller percentage last year than in several previous years. This translated into a significant slowing in the rate of rise of that very visible financial aid parameter, the allocation of unrestricted funds necessary to augment designated scholarship funds in the program. While the size of that allocation remains a very noticeable budget item, its very modest growth lends optimism to the next few years.

Adding to that good news was the establishment a year ago of three new Class Scholarship Funds and major additions to six already established funds during 1983-84. The support of the aid program over the years by alumni has been steady and substantial, but this group of new funds stands as a record number of dollars dedicated to this purpose in a single year. The investment income from these new funds did its part during the year to keep the unrestricted-funds allocation down.
During the last half of the fiscal year our attention and energy were riveted on the possible impact of proposals offered by the White House, some Senators and the Office of Management and Budget. Drastic changes to Federal student aid programs were involved, as a part of the administration's drive to reduce domestic spending. But at this writing the Congress had given these proposals short shrift and was on its way to reaffirming its continuing bipartisan support of Federal aid programs. Another threat of reductions in aid seems to have withered.

President Gray's Task Force on Undergraduate Financial Aid Policy has begun to release its findings to the MIT community through its Chairman (Professor Frank Perkins, '55) in a series of presentations and informal discussions. Its basic message--a reaffirmation of the soundness and the advantages of the present mix of financial aid policies, and the recommendation to continue them into the near future, at least--will be the subject of study and response over the coming year by the Faculty and others.

The Aid Office, in its turn, has begun a series of presentations to small groups, designed to familiarize key members of the community with the essentials of financial aid policy and with the desirability of continuing in the present mode; and to share our optimism that continuance is not only desirable but feasible. It seems to us that through the combination of happy external circumstances and disciplined internal stewardship, the aid program has weathered a storm that three years ago threatened to make it fiscally untenable without severe alterations.

Scholarship and Grant Programs

Little change was seen in the spectrum of resources for undergraduate scholarships. The endowment fund's interest income, the Federal grant programs, the gifts made to MIT for scholarship use, and the awards brought from outside sources by our students--all continued substantially at last years' levels, allowing for the modest rate of inflation. The strongest increase was in the ROTC program, which continues to thrive at MIT. The following table presents details for three consecutive years:

<table>
<thead>
<tr>
<th>Source</th>
<th>1982-83</th>
<th>1983-84</th>
<th>1984-85</th>
</tr>
</thead>
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<tr>
<td>Pell Grants</td>
<td>$795,000</td>
<td>$761,000</td>
<td>$755,000</td>
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<td>SEO Grants</td>
<td>1,039,000</td>
<td>1,111,000</td>
<td>1,294,000</td>
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<td>ROTC Scholarships</td>
<td>832,000</td>
<td>998,000</td>
<td>928,000</td>
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<td>Scholarship Endowment</td>
<td>3,538,000</td>
<td>3,831,000</td>
<td>3,953,000</td>
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<tr>
<td>Current Gifts</td>
<td>511,000</td>
<td>601,000</td>
<td>739,000</td>
</tr>
<tr>
<td>Direct Grants</td>
<td>1,425,000</td>
<td>1,460,000</td>
<td>1,644,000</td>
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<tr>
<td>Special Program</td>
<td>172,000</td>
<td>115,000</td>
<td>118,000</td>
</tr>
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<td>Unrestricted Funds</td>
<td>4,008,000</td>
<td>5,871,000</td>
<td>5,432,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12,320,000</td>
<td>14,748,000</td>
<td>14,863,000</td>
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</table>

Loan Programs

The past year featured intense nation-wide interest in programs that allow students and their parents to defer the cost of education. Many universities announced "new approaches to educational financing". Massachusetts and other states aggressively marketed "student" loan programs for parents, and new commercial deferred-loan programs for certain graduate students (those with high earnings potential) were introduced. While none of these appear to offer clear advantages to students compared with MIT's own Technology Loan Fund (TLF) and Parent Loan Plan, the proliferation of borrowing options outside MIT augurs well for an essentially unlimited pool of lending capital available to our students in the future.

*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 accounting records reported by the Comptroller or the Treasurer.
The shift in borrowing patterns described in last year's report continued--lower graduate student borrowing from the Guaranteed Student Loan Program and greater use of the TLF; an increase by undergraduates in National Direct Loan use, and less dependence upon the TLF. The following table shows these figures for three years:

<table>
<thead>
<tr>
<th>Loans</th>
<th>1982-83</th>
<th>1983-84</th>
<th>1984-85</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Awarded to Undergraduates</td>
<td></td>
<td></td>
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<td>Technology Loan Fund</td>
<td>$509,000</td>
<td>$484,000</td>
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<td>National Direct Loans</td>
<td>1,935,000</td>
<td>1,934,000</td>
<td>2,347,000</td>
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<td>Guaranteed Student Loans *</td>
<td>6,030,000 *5,982,000</td>
<td>*5,719,000 *</td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>8,474,000</td>
<td>8,400,000</td>
<td>8,804,000</td>
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<tr>
<td>B. Awarded to Graduate Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology Loan</td>
<td>$1,016,000</td>
<td>$1,632,000</td>
<td>$1,420,000</td>
</tr>
<tr>
<td>Guaranteed Student Loans by Commercial Lenders</td>
<td>3,442,000</td>
<td>3,011,000</td>
<td>3,390,000</td>
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<tr>
<td>Guaranteed Student Loans by M.I.T.</td>
<td>323,000</td>
<td>228,000</td>
<td>202,000</td>
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<tr>
<td>Sub-Total</td>
<td>4,781,000</td>
<td>4,871,000</td>
<td>5,012,000</td>
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</table>

* received by needy and non-needy students.

Student Employment

1984-85 showed an increase in the number of jobs available, and the average starting rate for off-campus jobs was well above the Federal minimum wage. The on-campus minimum wage was not increased for the first time in thirteen years. The number of students working on-campus remained constant.

The College Work-Study Program allocation remained at the 1983-84 funding level and was used entirely to subsidize the on-campus student employment program. Approximately two-thirds of the total 1984-85 allocation was used to subsidize undergraduate work, and one-third to subsidize graduate student teaching assistantships.

Staff Notes

After serving for two years on the SFAO's support staff, Lisa A. Oteri (A.B., Boston College) was promoted to the administrative staff in November. As an Assistant to the Director, Ms. Oteri will provide particular strength in the area of data systems support, as well as performing all of the regular duties of a Financial Aid Officer.

JACK H. FRAILEY
<table>
<thead>
<tr>
<th>Academic Staff Count</th>
<th>Professors</th>
<th>Associate Professors*</th>
<th>Assistant Professors*</th>
<th>Sr. Lecturers and Professors Emerit*</th>
<th>Sr. Lecturers</th>
<th>Sr. Research Scientists</th>
<th>Instructors</th>
<th>Technical Instructors</th>
<th>Sr. Research Associates</th>
<th>Postdoctoral Associates</th>
<th>Research Assistants</th>
<th>Teaching Assistants</th>
<th>Instructor Grad</th>
<th>Total</th>
<th>Visiting Professors</th>
<th>Others</th>
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<td>-</td>
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<td><strong>SCHOOL OF ARCHITECTURE AND PLANNING</strong></td>
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<td><strong>Total</strong></td>
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<td>16</td>
<td>12</td>
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<td>16</td>
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<td>61</td>
<td>71</td>
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<td>223</td>
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<td>5</td>
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<td>6</td>
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<td>1</td>
<td>12</td>
<td>169</td>
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<td>16</td>
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4. Not included in preceding total
5. Visiting Professors include 40 Professors, 25 Associate Professors, 12 Assistant Professors.
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| Applied Biological Sciences, XX       | -   | -   | -   | 117 | 2   | 119 | -   | -   | -   | -   | -   | XX   |
| Biology, VII                         | 59  | 75  | 63  | 150 | -   | 347 | -   | 1   | 1   | 6   | 8   | VII  |
| Biology, VII-A                       | 4   | 4   | 5   | -   | -   | 13  | -   | -   | -   | -   | -   | VII-A |
| Biology, VII-B                       | 11  | 13  | 15  | -   | 20  | 22  | -   | -   | -   | -   | -   | VII-B |
| Biology, VII-W (Woods Hole)          | -   | -   | -   | -   | 61  | 61  | -   | -   | -   | -   | -   | VII-W |
| Chemistry, V                         | 42  | 42  | 29  | 206 | 2   | 321 | -   | 1   | -   | 1   | 2   | V    |
| Earth, Atmospheric, and Planetary Sciences, XII | 9   | 9   | 14  | 113 | 3   | 148 | -   | -   | -   | 1   | 1   | XII  |
| Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole) | -   | -   | -   | 61  | -   | 61  | -   | -   | -   | -   | -   | XII-W |
| Mathematics, XVIII                   | 46  | 52  | 51  | 131 | 9   | 289 | -   | 4   | 8   | 12  | -   | XVIII |
| Physics, VIII                        | 65  | 63  | 77  | 299 | 2   | 506 | -   | -   | 4   | 4   | -   | VIII |
| Total                                 | 236 | 258 | 254 | 1,097| 18  | 1,863| -   | 2   | 5   | 20  | 27  | Total |

| Health Policy and Management, HPM     | -   | -   | -   | 7   | -   | 7   | -   | -   | -   | -   | -   | HPM |
| Health Sciences and Technology, HST   | -   | -   | -   | 70  | -   | 70  | -   | -   | 47  | 47  | -   | HST |
| Undesignated                         | 78  | -   | -   | -   | 78  | 9   | -   | -   | -   | 9   | -   | Undesignated |
| First Year                           | 1,063|     |     | 78  | 1,063| -   | -   | -   | First Year |
| Grand Total                           | 1,063| 1,149*| 1,097*| 1,227*| 4,936| 154| 9,626| -   | 12  | 6   | 13  | 333| 364| Grand Total |

(Not included in the above figures)

| Non-Institute students from Brandeis | 1   | 1   | -   | -   | -   | 2   | -   | -   | Non-Institute students from Harvard |
| Non-Institute students from Harvard  | 25  | 48  | 22  | 36  | 263 | -   | -   | 394 | Non-Institute students from Tufts   |
| Non-Institute students from Tufts    | 24  | 38  | 7   | 8   | -   | -   | 77  | -   | Non-Institute from Wellesley       |
| Non-Institute from Wellesley         | 10  | 46  | 54  | 71  | -   | -   | 171 | -   | Non-Resident graduate students

1Non-Resident graduate students
2These totals include 2 student in the second year, 11 students in the third year, 3 students in the fourth year on Foreign Study; 2 students in the third year on Domestic study.
3Included in previous totals.
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First Year 309

Grand Total 309 282 264 302 930 49 75 2,211

1Also included in Classification of Students
Total undergraduate women 1,157; 10 special undergraduate women are included.
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Office of Sponsored Programs

For fiscal year 1985, the total volume of sponsored research performed on campus approximated $241,756,000, an increase of 9.1 percent over fiscal 1984 volume of $221,581,000.

The level of research support provided by the major Federal agencies other than NASA increased in real dollar terms. Research sponsored by NSF increased by close to 10 percent after declining last year, while HHS supported research increased by 10 percent compared with 18 percent last year. The 9.7 percent and 7.8 percent increases in DOD and DOE research funding, respectively, were slightly greater than in 1984.

With respect to non-Federal sponsorship, the 21 percent increase in industrial support follows last year's remarkable increase of 40 percent.

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<td>19,183</td>
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<td>11,811</td>
<td>10,400</td>
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<td>Total Federal Sponsorship</td>
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<td>Foundations and Other Nonprofits</td>
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<td>9,654</td>
<td>11,614</td>
<td>11,699</td>
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<td>Other</td>
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<td>2,627</td>
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<td>Total Non-Federal</td>
<td>5,905</td>
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<td>24,711</td>
<td>31,573</td>
<td>34,707</td>
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<td>Total Research Volume</td>
<td>55,828</td>
<td>141,306</td>
<td>163,122</td>
<td>183,970</td>
<td>191,970</td>
<td>199,273</td>
<td>221,581</td>
<td>241,725</td>
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</table>

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:

Export Controls and Critical Technology

As noted in last year's report, the Department of Defense issued a draft policy in June 1984 which stipulated that "the mechanism for control of fundamental research in science and engineering at colleges, universities and laboratories under contract to U.S. Government agencies is classification... No restrictions
may be placed upon the conduct or reporting of fundamental research that has not received national security classification." In October, DOD announced that all unclassified contract research supported by 6.1 (basic research) funding shall be considered fundamental, as well as such research performed on campus at a university and supported by 6.2 (applied research) funding, with rare exceptions. In those cases, and for research supported by 6.3 funding, which is very small on campus, any restrictions would be part of the contract negotiations. No such restrictions have been accepted, however, for on-campus projects under current MIT policy. The DOD policy has to a large extent resolved some of the difficulties encountered in proposed contract restrictions on publications and on the employment of foreign nationals.

Star Wars Research

MIT research investigators have submitted a number of proposals under the Strategic Defense Initiative (Star Wars) program, but participation in the program has not been without controversy. In his commencement address, Paul Gray took exception to the Pentagon's apparent manipulative efforts to garner implicit institutional endorsement for S.D.I. MIT has stated that it has not endorsed the program or agreed to play a major part in it, and does not view itself as part of a Star Wars sponsored consortium solely because MIT scientists or engineers apply for and receive contract support under a program involving other university scientists and engineers. Concerns have been voiced over possible export control restrictions and classification, the reported transfer of existing research projects to the Star Wars program to develop a Star Wars constituency, and whether, despite statements that such money would be handled as unclassified fundamental research at universities, there might be mid-course corrections resulting in classification or other controls.

Committee on Software Rights

At the close of the year, the Committee on Software Rights had completed deliberations and was preparing its recommendations for an MIT policy with respect to ownership rights and the dissemination and distribution of software resulting from Institute programs, whether educational programs such as ATHENA or research projects.

Federal Rights-in-Data Policy

With the passage of Public Law 96-517 in 1980, a uniform approach on rights in inventions resulting from Federal funding agreements was adopted, which provided ownership and control to universities and other non-profits with the goal of enhancing technology transfer and improving this country's technological competitiveness in world markets. At the close of the year, however, the rights in data regulations proposed by the Federal agencies appeared to reflect a policy of Federal control over the dissemination and transfer of technical data and computer software which could have adverse consequences for the university community. MIT and other universities are now communicating their concerns over the impact of these regulations, and the issue is likely to persist in fiscal 1986.

Competition in Contracting

Legislation enacted in 1983 established new requirements to ensure full and open competition in procurement. Although oriented toward the procurement of hardware, spare parts and supplies, and motivated by recent abuses in the Department of Defense, the regulations appeared in their early stages to apply to universities in a way that would create long delays in awards by requiring publication of notices in the Commerce Business Daily or long internal agency reviews and justifications before a contract could be awarded. The university community expressed concern over the impact on unique and innovative unsolicited proposals. However, as noted in last year's report, another public law passed in June 1984, and the implementing regulations, turned out to be more responsive to university needs. Henceforth, proposals submitted in response to broad agency announcements of their research interests will be considered to be competitive proposals, and the publication and review delays should not be serious. Several other exemptions to full and open competition may also prove of use to universities in some situations.

NIH Indirect Cost Freeze

In order to contain what it perceives to be the growth of indirect costs, NIH has in several prior years proposed language in appropriations bills that would limit the payment of indirect costs on NIH grants to 90 percent of the amount otherwise allowable under Federal cost principles. Such provisions have been
eliminated each year by Congress. For fiscal 1986, NIH has proposed that the indirect cost rate applicable to NIH grants not exceed the fiscal 1985 rate (being applied as of December 31, 1984), or the actual rate whichever is lower. A number of individual universities are protesting this proposal, which has not yet been acted on by Congress. It would have no impact on MIT, as currently proposed, since the MIT indirect cost rate for fiscal 1986 will be less than the 1985 rate.

PERSONNEL CHANGES

During the year the following changes occurred in the Office of Sponsored Programs: Four new assistant directors were appointed - Merrily D. Sterns, formerly an assistant director in the Boston University Office of Sponsored Programs, as of July 1; Italo A. Rufo, formerly a contract administrator in the Office of Naval Research at MIT, as of July 9; Kathaleen R. Mercier, formerly administrative officer in the Sloan School Center for Computational Research in Economics, as of August 1; and Joan T. Kyhos, formerly an assistant director in the Boston University Office of Sponsored Programs, as of October 10. Effective August 1, Karen Hersey transferred from the MIT Patent Office to OSP as a coordinator. Jonathan Bartels, an OSP assistant director, transferred as of August 31 to the MIT Materials Processing Center as Financial Officer, and Susan Woodruff, an OSP Assistant Director, resigned on June 30 to relocate in southern Massachusetts.

GEORGE H. DUMMER
Senior Vice President

This year several major organizational changes were implemented as part of a continuing program to increase productivity while at the same time controlling costs.

Information Systems was restructured into four operational units - Administrative Systems, Information Services, Operations and Systems, and Telecommunication Systems - in order to increase its responsiveness to both Institute needs as well as future technological developments.

The Property Office, formerly a division of the Office of Facilities Management Systems, was awarded departmental status in December and J. Terence Meehan was appointed Director.

In Physical Plant, responsibility for the Central Utilities Plants was transferred from Utilities and Engineering to Building Operations at the beginning of the year. This change reflects a management philosophy that energy saving possibilities can be maximized by more closely relating individuals involved with the generation of steam and chilled water with the Operations Center and the building operators.

Responsibility for the Property Office and Purchasing and Stores will be assumed by the Vice President for Financial Operations at the beginning of next year. Transfer of these two departments to the financial area should increase operating efficiency and provide better overall service to the user community. In addition, responsibility for the Child Care Office will be assumed by the Vice President in the Office of the President at the beginning of next year.

As part of our overall effort to reduce operating costs, we are examining the possibility of moving our community use buildings toward a more self-sufficient auxiliary status. The buildings and their programs, including the Stratton Student Center, Kresge Auditorium, the Chapel, and Walker Memorial, have been organized into what is being termed the Campus Activities Complex and the process by which we hope to move the Complex to auxiliary status has become known as "The Transition Project".

This Transition Project, initiated in January of 1985, is designed as a two year process. By this process we hope to reduce the impact of the Campus Activities Complex on the Institute budget while at the same time enhancing services and support for the wide variety of constituencies who use the facilities.

Following are the individual department reports:

WILLIAM R. DICKSON

Campus Police

The Campus Police continued to provide 24 hour professional police and emergency medical services to members of the MIT community. 1,939 complaints were received by the department, up 19 percent compared to last year. Of these, 22 were in the crimes against persons category, down 12 percent from last year and the lowest figure in the past five years.

Larceny continued to be the most frequently committed crime on campus. Institute property losses for the year totalled $91,368.39. Personal property (non-residence) losses were $32,890.90 and residence hall losses were $35,852.37, both of which were due primarily to wallet and pocketbook thefts.

This year's total of 30 stolen vehicles was seven lower than the previously recorded ten year low set in 1980 and repeated in 1982.

Once again, emergency medical service increased. A total of 3,029 runs, including emergencies, transfers, and medical shuttles were performed.
A total of 11,743 escorts were conducted during the year, an increase of 4 percent over last year.

JAMES OLIVIERI

Child Care

Child Care Office

This year was highlighted by a variety of activities which strengthened the existing relationship between the Child Care Office and the MIT community. Offerings included a greater number of children’s swim sessions and Independent Activities Period activities as well as a series of well attended brown bag lunch discussions concerning topics of interest to the working parent. A total of 41 children from infancy through age 12 participated in Commencement Day child care organized by the Child Care Office. In cooperation with Technology Children's Center, the office was involved in the design and tabulation of a child care needs survey which was distributed throughout the Institute.

The Child Care Office continues to serve the many child care needs of the MIT community by providing information and referral services. The Family Day Care system, operating on- and off-campus, is used primarily for infant and toddler care and some flex-time care for pre-schoolers. The office staff assisted a number of prospective providers of care in the process of obtaining state licensing and continues to visit licensed homes regularly. A sizable number of family day care providers participated in various Office-sponsored English lessons, tax workshops, activity and film sessions for children, and social gatherings. Together with a regularly published newsletter, these activities have provided a greater sense of community and professionalism for providers.

Overall demand for child care of all kinds continues to increase. The need for more licensed providers remains constant and waiting lists for available spaces have existed throughout the year.

Technology Children's Center

The 20th Anniversary of the incorporation of Technology Children's Center (TCC) was the Center’s high point of the year. A large number of families whose children had attended TCC returned for the special festivities. The TCC continues to offer center-based care to about 100 children throughout the year. With the discontinuation of the Kindergarten/Extended Day, total day care spaces were increased to 30. The Nursery School summer session was extended from six to eight weeks. All TCC programs are designed to promote social, emotional, and cognitive development and the Center encourages informal participation of parents. Throughout the year, TCC served as a student field placement site in education for several area colleges and universities.

TCC and the Child Care Office continue to work together toward increased utilization and sharing of resources and services within the Institute and the larger community.

LUISE FLAVIN

Endicott House

This year business increased significantly. For the first time, gross revenues exceeded $1 million, representing an 18.2 percent increase compared with last year. The primary reason for this increase is the general acceptance of Brooks Center as a viable and effective conference center.

Our staff reorganization effort was completed during the year and a new marketing program was initiated in order to achieve the growth in business required to support the expanded facility. In addition, the programming for a specialized accounting system that will enable management to compare the financial results of Endicott House with those of the industry in a more timely and effective manner was also initiated.
In order to provide guests with the highest standards of service and to maintain the facilities and grounds at a similar level, various improvements and purchases were completed. In addition, an extensively revised menu has recently been introduced, offering guests a greater selection of entrees and a broader range of prices.

We look forward to the coming year. The Sloan School of Management's Senior Executive Program will have a record attendance during the fall term and advanced reservations made for next year indicate an exceptional year.

ALBERT H. FOREST

Graphic Arts and Audio Visual Services

The total dollar volume of business of $4.4 million was approximately the same as last year. The trend toward use of the Copy Centers for duplication and reproduction as opposed to the photodirect and electrostatic process in the Offset Department continued. Revenues were up by approximately 7 percent in the Copy Centers and down by the same amount in the Offset Department. All other departments remained approximately at last year's levels.

Effective July 2, 1984, various services from Educational Video Resources (EVR) were transferred to the Audio-Visual Department. These services include the rental of playback units, rental of video projectors, maintenance of classroom monitors, and duplication and sale of video tapes. Taping and editing of classroom materials remains a function of EVR.

Major equipment purchases or rentals included new Model 9500 and 9900 Xerox copiers in the Building 11-004 Copy Center. In addition, the department purchased 16 new Xerox and Ricoh copiers to rent back to various MIT departments, many as replacements for older copiers, some for new installations. There are now 26 such copiers being supervised and administered by Graphic Arts.

Other changes included the purchase and installation of a new telephone system at our N42 location, additions and enhancements to our Typesetting Department, and improvements to our computerized offset/mail service internal reporting and cost control system.

JAMES W. COLEMAN

Housing and Food Services

Substantial changes were implemented during the year in an effort to assure that we continue to meet our goal of providing the best possible housing and food services for our students. We improved our Housing operation by decentralizing much of the immediate decision-making authority and responsibility by moving it to the individual House Managers. House Managers now have the authority to respond quickly to situations that arise, and the full responsibility for the physical environment, employee resources, and budgeting for their House. This approach has already produced valuable input from the House Managers and other operating personnel for identifying and targeting departmental policy actions to meet our Institute goals.

The department spent over $1 million in renovations and repairs in an ongoing effort to upgrade the Housing system. Major structural work took place at East Campus where extensive lintel and brick restoration was performed. New bathroom construction was also accomplished. At the West Campus Houses, a recarpeting program was initiated. A third elevator service person was hired on a shared cost basis with the Physical Plant Department for campus-wide elevator coverage. A comprehensive program for mechanically updating elevators was started for the major Housing and Food Service Department elevator service areas.

The Food Service operation in the dormitory dining rooms was changed to predominantly A La Carte during the year in response to the students' desire for variety and flexibility. Baker House expressed a desire to continue its Common's dining program with some A La Carte adjustments to meet their House program and will be the only Commons House in the Food Service system next year.
We received invaluable student input to our Food Service planning this past year. We had strong support from Baker, MacGregor, and McCormick Student Food Service Committees and individuals. Such outstanding efforts by students in gathering and communicating their constituents' Food Service ideas and needs made for fast turn around in our department's decision-making process. This should continue since clear communication lines have been created.

The Advisory Board and management of the Faculty Club have responded over the past year to the long-term goals of providing a more cost effective operation while serving its primary function as a center of academic and social exchange. This has been accomplished by planning and implementing a full scale renovation of the Club that will involve two summers of construction work and important changes to the physical layout. The Club has responded to Institute-wide cost reduction goals by further reducing the burden of its subsidy. The planned renovation of the club will, through substantial integration of labor, further reduce this subsidy and bring us closer to our ultimate goal of financial independence. New services to our membership included our complementary hor d'ouvres program in the bar and special nights where feature menus are offered.

Of special note is the retirement of Salvatore Lauricella after 34 years of truly superb contribution to MIT and our Food Service System.

As a final note, the departmental reorganization effort we began last year is nearing completion. We expect a stronger, more responsive service organization to result from this effort and I want to take this opportunity to thank the community for their support during this transition year.

HARMON E. BRAMMER

Information Systems

The Information Systems group began 1985 with a significant organizational realignment. The group's restructuring was motivated by discussions late in 1984 indicating that the group as then constituted needed to be restructured in order to increase its responsiveness to both Institute needs as well as future technological developments.

As a result, Information Systems now has four operational units:

1) Operations and Systems with responsibility for providing computer operations, production service, and systems programming support for the Institute's centrally managed computers as well as providing similar facilities management services for other Institute organizations.

2) Administrative Systems with responsibility for setting standards and procedures for, and developing and maintaining those software systems necessary for the Institute to perform its business and administrative functions.

3) Telecommunications Systems with responsibility for providing the full range of telecommunications services, including a campus-wide computer network, necessary to meet the Institute's needs.

4) Information Services with responsibility for the comprehensive support of end-user computing at MIT.

Statements highlighting the activities of each of these operational units appear later in this report.

Several events of the year are of particular significance and merit specific mention. The first of these is the John von Neumann Center. MIT and 11 other sister institutions joined together in early 1985 to form the Consortium for Scientific Computing, Inc. which has now been selected by NSF to develop a major new supercomputer facility. Computers at this facility will be available to the Institute's faculty, staff, and students via a high-speed link from the MIT campus computer network. Computers at the Center will execute instructions at rates in excess of one billion floating points per second.
Second, is the continued growth of Project Athena and the recognition that the Institute has already become dependent upon these resources, expecting reliable, high-quality services to be available. This has led to an agreement between Project Athena and Information Systems whereby Operations and Systems will provide facilities management services for Athena's deployed machines.

And, third, is the rapid growth in interest in and deployment of distributed workstations from small personal computers to much more powerful machines such as DEC Micro-VAX's, Sun workstations, and Symbolics LISP machines. This growth will put pressure on the campus computer network and upon Information Services as users seek "information" connectivity with the rest of the Institute and advice, help, and opportunity to acquire hardware and software at attractive prices.

JAMES D. BRUCE

Administrative Systems

This has been a year of transition and accomplishment for Administrative Systems (AS). Changes have occurred in the group's responsibilities, its orientation toward the Institute administrative community, and the technology with which it works. At the same time, major milestones were achieved in several project areas, new projects were undertaken, and plans for the next four years were formulated.

Hardware ownership, operation, and management of production job flow for administrative clients moved from AS to Operations & Systems. Administrative Systems now concentrates on specifying, implementing, and maintaining business applications software, with emphasis on providing standards, procedures, and guidance for systems development or acquisition. In several areas -- including Physical Plant, Medical, Student Financial Aid, Purchasing/Accounts Payable, Telecommunications -- AS staff are working with administrative offices as well as vendors and independent contractors to identify and meet application needs. Staff engaged in the more traditional analysis, design, and programming activities reached major milestones in several ongoing projects: Pension Accounting Systems, Personnel, Payrolls, Alumni/gifts, Life Income Fund/Investments, Student Loans, and Budget. Work began on a General Ledger system and on assessing needs for Resource Development.

Most applications running on the older IBM 370/148 in the Ford Building have been moved to larger IBM administrative mainframes. After the Student System was moved and two DEC VAX 11/785's were installed for Purchasing/Accounts Payable and Budget/General Ledger, the active administrative mainframe community typically numbers over 200 online users every day. One measure of the Institute's growth in administrative computer usage during the five years since applications began moving off the 370/148 is computing power: administrative mainframe computing has growth from one machine capable of only half a million instructions per second (mips) to four production machines with an aggregate capability of about ten mips.

After years of working with MIT's central administrative offices on systems that support their data processing requirements, AS has begun investigating the computing needs of administrators in departmental and laboratory headquarters. With a survey of administrative computing in the School of Engineering and with prototype systems which provide access to accounting data on both microcomputers and mainframes, AS has begun to address needs for automated administrative information capabilities across the campus. These projects have allowed AS and users to explore issues associated with distributing business data on a campus network. Problems of assuring data privacy, security, and authenticity are key concerns, as are intentions to present to campus office staffs a consistent, coherent workstation venue which accommodates data transfer to and from central administrative systems.

While demand for mainframe computer cycles in administrative processing remains strong, a trend toward microcomputing and local area networks is underway in both central and departmental offices. In most micro-based applications, connectivity to mainframes for data sharing, for electronic mail on campus and with other institutions, and for special capabilities, such as volume printing, soon becomes a substantive issue. The AS staff has worked to assure connectivity by providing help with needs assessment, product evaluation, network planning, micro application development, and micro/mainframe database linkage facilities.
After a period of reorganization and redirection, AS now sees three goals as paramount for the future:

1) Facilitate collecting and distributing automated administrative data between central and departmental offices;

2) Further integrate processing of central Institute data; and

3) Provide effective infrastructure for applications implementation, integration, and distribution.

Working together with central and departmental office staffs, with other Information Systems units, and with vendors, AS anticipates applying office technology tools to meet the information era needs of MIT's administrative community.

MARILYN A. McMillan

Information Services

This has been a year of transition in which Information Services has moved from being an organization primarily devoted to the support of a limited clientele of mainframe computing users to one which is providing services to the Institute as a whole. This year has also seen an increase in cooperative ventures both within Information Systems and with other Institute organizations. Progress has been made in support for Project Athena, personal computer sales, and support, training, documentation, and administrative computing support.

At the beginning of the first and second terms, members of the staff introduced hundreds of students who were starting classes using Project Athena's computing environment to the UNIX operating system and several of the available utility programs. Information Services also wrote an introductory manual on the use of RS/1 mathematical/statistical software and began an "Athena Assistance" memo series.

In October 1984, Information Services opened its new Microcomputer Center. The Center, in cooperation with the Office of Laboratory Supplies, sells microcomputer hardware and software at a considerable discount to both departments and individuals at the Institute. Apple, DEC, and IBM personal computers are available through the Center.

In addition, the Microcomputer Center and Consulting Services staff also provide pre-purchase needs analysis and consulting at a level not available from outside vendors. Advice is available on the choice of systems and software for database, word processing, financial analysis, mathematical/statistical, and other applications. The staff also teaches a series of two-hour seminars introducing students and staff to the software available in these application areas.

In November, Information Systems participated in the Working Group on Support Staff Issues' Office Automation Fair. The Model Office, set up by Information Services in cooperation with Administrative Systems to demonstrate how information technology could be used in Institute offices, was viewed by the Working Group as the centerpiece of the fair.

Recognizing the largely unfulfilled needs of Institute staff for training in the use of personal computers and office systems, Information Services has added a Manager of Training to its staff. He will be responsible for being cognizant of the information technology training needs of the Institute's staff, arranging and making the Institute's staff aware of training opportunities, and insuring the quality of the training presented.

In a cooperative effort with other Information Systems groups, a new online news service was established to provide timely dissemination of information on services provided to the client community. The news system will eventually be extended to serve the campus network.

In addition to providing assistance to administrative offices in the area of personal computing, Information Services has begun to acquire expertise in the use of admini-
strative end-user computing tools on Information Systems mainframe computers. In the course of the coming year, online consulting and problem-tracking services will be extended to Administrative Systems clients.

RICHARD D. SCOTT

Operations and Systems

Operations and Systems -- with new hardware, software, and responsibilities -- has also experienced a series of major changes during the year.

Prompted by the need for increased computer power and disk space to satisfy the needs of the administrative workload and for more physical space in the computer room, an agreement was negotiated with IBM to replace some of the older hardware with more current equipment, providing 15 percent more CPU power, 25 percent more disk capacity, considerably better reliability, and an excellent growth path. The new hardware also has freed about 20 percent of the total space in the computer room (to be used in coming months to house machines supporting services available on the computer network) and uses about 25 percent less electricity and air conditioning. The conversion to the new hardware, begun in April, is scheduled for completion by September.

During the year, three DEC VAX's were installed for administrative use. The Honeywell Multics system was upgraded with an additional two million words of memory and a new disk drive was installed to replace three of the older models. An IBM communications controller was also installed permitting more ASCII terminals to access the academic/research IBM system in full screen mode. When this device is completely integrated into our environment, it is possible that similar devices can be used to provide access to the administrative systems.

A number of changes have also been made in operating system software. A new version of the VM/SP software was installed on the new IBM 3083. This version is called HPO (High Performance Option) and is required to take advantage of some of the new features of the 3083. Although internally it is a major change, the user interface remains essentially the same. A new version of the online meeting system, Forum, was installed on Multics. This product is licensed to Honeywell and is used at over 25 sites. We have just signed a contract with CCI-Bull in France for marketing this product in that country. New releases (4.0 and 4.1) of the VAX/VMS systems were also installed on the DEC VAX computers.

New usage accounting systems for the IBM machines which provide increased flexibility and the ability for users to query the status of their own accounts were also implemented.

During the year, Operations and Systems began two major new services -- facilities management and personal computer maintenance. As its first major facilities management responsibility, it has assumed operational and systems programming responsibilities for the Project Athena clusters.

A PC maintenance facility is being developed in Building W91. This facility will begin to provide service to IBM PC's early next year and plans to service Apple and possibly DEC systems in the future.

Conversion of the workload on the 370/148 to the other systems is nearing completion. The operating schedule for the 148 has been reduced and decommissioning of the machine is expected by October 1985.

ROGER A. ROACH

Telecommunications Systems

The near-term strategy for Telecommunications Systems is to provide a coherent, universal, integrated, easily accessible telecommunications system throughout MIT. To that end, Telecommunications Systems now provides several new services to the campus.

The first phase of the campus computer network has been completed. This network has been designed to provide high-speed data communications to as many on-campus computer systems as possible. Gateways connecting the campus computer network to local area
networks are located in a number of campus buildings and currently the major network client is Project Athena.

MIT is a member of the Consortium for Scientific Computing, Inc., which is in the process of developing the John von Neumann supercomputer facility in Princeton, New Jersey. MIT will act as a communications gateway to the Center for Brown and Harvard Universities in addition to itself. High-speed lines will permit communication at 1.544 megabits per second with the facility. The von Neumann Center is scheduled to become operative in the first quarter of calendar 1986.

New and direct telecommunications connectivity via microwave is near completion from MIT to the Woods Hole Oceanographic Institution, and from MIT to Bolt Beranek & Newman (BB&N). The BB&N facility will be used for interconnection to an Advanced Research Program Agency (ARPA) earth station, sited at BB&N.

At the beginning of the year, the MIT video cable network became an operational responsibility of Telecommunications Systems. One of its activities during the year was to transmit live cablecasts of weekly VLSI seminars from MIT to the Lincoln Laboratory. These telecasts made use of a microwave link from MIT to the Prudential Building where the signal was rebroadcast over the Institutional Television Facility Service low-power educational microwave system owned and operated by the Boston Catholic TV center.

Late in fiscal 1984, Telecommunications Systems, in response to the campus' need for improved message transport services and the continuing increase in communication costs, developed a Request for Proposal (RFP) calling for a state-of-the-art digital switching system. This proposal was provided to vendors in May 1984. Proposals were received from eight vendors in response to the RFP in September 1984. Following several months of negotiating with vendors and researching the technologies proposed by them, an ad-hoc committee of faculty and staff working with Telecommunications Systems agreed that the best of the technologies proposed was the 5ESS switch built by AT&T Technologies. A recommendation was made this June to the senior administration that an order be placed with AT&T Information Systems, one of the vendors proposing this switch, to purchase the 5ESS switch and have it placed into service in the summer of 1987.

The 5ESS switch is fully digital. Its architecture emphasizes flexibility through the use of distributed processing, and has a modular growth plan. The modular design allows switching capacity, system interfaces, and call processing capacity to be added incrementally.

Assuming that this proposal will be accepted, the Institute's Centrex service as well as "dormphone" will be replaced in about two years with an Institute-owned PBX. In the interim, the Institute will continue to use its present services. In this regard, MIT has intervened in hearings initiated by the Massachusetts Department of Public Utilities in the matter of Centrex rates seeking Centrex rate stability during the period prior to the replacement of that system.

MORTON BERLAN

Office of Facilities Management Systems

Facilities Management

The Office of Facilities Management Systems (OFMS) is responsible for the collection, maintenance, and reporting of data for more than 26,800 individual spaces at MIT, comprising 7.8 million net usable square feet. Using INSITE 3, an MIT-developed space accounting system, two major updates to the space inventory were completed, each followed by the distribution of standard reports to academic and administrative offices. Numerous special reports were also requested throughout the year. Also, historical facilities data were updated and distributed in graphic and statistical form, and the Building Data Report was again updated and distributed.

The maintenance of MIT's room numbering scheme for both existing and new facilities continued as did the maintenance and production of MIT's 286 scaled floor plans. Additionally, the two year task of electronically digitizing MIT's floor plans began in mid-May. Completion of this effort will allow for the electronic distribution of MIT's floor plans and an automated way to easily update those plans at the same time the INSITE database is being updated.

400
Insite Consortium

Another major responsibility of OFMS is to provide support to the existing Consortium of external users of the INSITE technology, as well as to foster the continued growth of the Consortium in both its membership and the quality of its facilities management. Each member employs the INSITE system and its associated methodology both to manage their inventories of building space, as well as to share their knowledge and experience in this area with MIT.

Support activities peaked again during the year in the forms of telephone contacts from members, visits by departmental staff to members' sites, the conducting of seven training courses, the publication of a quarterly professional journal, and record attendance of facilities managers, attracted nationally, at the two-day 13th Facilities Management Conference at MIT. A two-day course in Facilities Management for Senior Executives, available to nearly 50 non-INSITE users, was presented again this year.

Computer Support

Of continued significance this year was the effort of providing INSITE 3 system support for MIT and the Consortium. Included in that effort was the design and programming of required INSITE 3 interactive front-end enhancements. Also, this year's efforts in completing the design and programming of the INSITE-CAD systems culminated in the call for Beta test sites for the systems amongst the Consortium membership. Also completed was the design of a microbased INSITE query system to download INSITE data from the mainframe to an IBM PC/AT for querying, reporting, and linking to other software modules such as statistical packages. Most of the next year will be dedicated toward the programming and testing of this new system, with an eye to providing it to any MIT organization who would like a desk-top ability to query pieces of the facilities inventory database.

Property Management

Under the leadership of J. Terence Meehan, the Assistant Director of Property Management in OFMS, the Institute's property functions reached a point where its purposes were best served by establishing it as a separate department. This was achieved in December when the Property Office became a separate department.

KREON L. CYROS

Physical Plant Department

This year marked a number of changes in both management and personnel. At the beginning of the year, the responsibility for the Central Utilities Plants was transferred from Utilities and Engineering to Building Operations. This change reflects a recognition of the energy saving possibilities brought about by more closely relating those individuals involved with the generation of central steam and chilled water with the operations center and the building operators. In order to have an effective energy conservation strategy, these three groups must work as a close knit team, communicating continuously.

After an extensive study and review process, Physical Plant received approval to purchase software and hardware for an on-line plant management information system to replace its ten year old batch system. We are working with an outside vendor to modify its maintenance management system to meet our requirements in plant areas such as labor and utility cost distribution, payroll, inventory, and work order control, logging of trouble calls, etc.

Several retirements of senior personnel occurred during the year including William Combs, Staff Superintendent and Robert Cavanaugh, Assistant to the Director for Space Administration.
Utilities and Engineering

The pattern of recent years has continued with the increased use of electrical energy without any corresponding increase in floor space occupied. This disturbing trend toward more energy intensive research activity across the campus shows no signs of leveling off. Our higher electric consumption combined with continued instability and increases in electric rates pushed the overall campus cost of utilities to a new high in spite of reductions in both the unit cost and use of oil and gas for heating and air conditioning. These fuel cost reductions reflect further improvement in energy conservation effectiveness on campus.

The engineering group provided or coordinated engineering services for central chilled water extensions in the main group of buildings and to the Francis Bitter National Magnet Laboratory (NW14) on the northwest campus where use of less energy efficient absorption chillers will be discontinued. In addition, substantial electrical work was done in replacing the high voltage service from Cambridge Electric in order to improve reliability of electric service for this important research facility.

The program to provide air conditioning for areas in the main group comparable to our newer facilities continued with projects in Buildings 1, 2, 3, 5, and 8.

At the end of the year, Charles Webber, Engineering Assistant, retired after a 34 year career at MIT.

Architecture, Engineering, and Construction

Construction activity on campus was severely delayed this year by a seven-week strike in the construction trades. This critical job action in September and October brought all major jobs to a virtual standstill and interrupted the normal pace of construction. Both major construction projects scheduled for completion during the year experienced significant delays.

The Arts and Media Technology Building was substantially completed by year end. Partial occupancy was possible prior to completion and the headquarters activities of the Committee for the Visual Arts, the first occupant, moved into the building during January. The Albert and Vera List Galleries were dedicated in March with a gala opening exhibit of modern art. Occupancy of the building by other groups has continued steadily through the spring.

The major renovation of the former Information Systems Building on Vassar Street for the Microsystems Technology Laboratory will also finish later than expected. Early occupancy of office spaces occurred during the spring and the building will be substantially completed and fully occupied by late summer. Installation of the sophisticated ultra-clean chip-processing equipment will continue well into the next year.

Other renovation projects with a total cost of slightly over $3.5 million completed during the year include: the Martin Center for Engineering Design on the fourth floor of Building 3, Chemistry research laboratory facilities on the second and third floors of Building 2 (north), and the Center for Real Estate Development on the top floor of the Armory (W31) on Massachusetts Avenue.

There is no new building construction activity underway and none on the drawing board with the exception of a proposed project to upgrade and expand the Rotch Library in Building 7. Major space change renovation work is scheduled in Buildings 5 and 7 for Ocean Engineering; in N51 and N52, the former EPSCO properties, for Architecture; in Building 16 for Applied Biological Sciences; in Buildings 12 and 13 for Material Sciences and Engineering; in Building 20 for both the Center for Space Research and the Humanities Department; and a Faculty Club renovation in the Sloan Building (E52).

Athena renovation projects continue to be a major source of design and construction activity with seven new computation clusters slated for completion during the next year.

Harry Portnoy, Campus Architect, retired after 18 years of service to the Institute in the areas of programming, design, and construction administration.
Support Services and Building Maintenance

After a year of experience with more efficient mechanized cleaning equipment and a revised training program for cleaning personnel, we believe that a reasonable standard of housekeeping is being maintained in spite of personnel reductions. Studies continue on mail sorting and distribution to determine if mechanization can reduce the costs of handling 60,000 pieces of local and U.S. Mail plus 500 packages daily.

As part of our program to address deferred maintenance, we have awarded a major parking garage rehabilitation contract in excess of $2 million to cover concrete repairs, traffic surface restoration, and structural steel painting for the East, West, and Albany Street facilities. The majority of the work will be accomplished this summer by sequentially shutting down the garages with less disruptive activities continuing into the fall.

During the year, William McRitchie, Assistant Manager of Grounds retired after 30 years of service.

Building Operations

As described earlier, Building Operations was given responsibility for the Central Utility Plants at the beginning of the year and efforts were focused on working out a smooth transition for this major change. A new chief engineer was appointed on January 1, 1985 and George Gibney and George Reid, Chief Engineer and Assistant Chief Engineer respectively, retired June 30, 1985 with 40 years of combined service to the Plant. In addition, we are transferring much of the utilities plant manual record keeping and processing to a personal computer which will be used to generate operational and management reports.

A survey of 25 of our older and higher repair frequency elevators was carried out by an outside consultant to help us in developing a program for both rehabilitation and better day-to-day maintenance. As a result, we have identified a substantial level of deferred maintenance which we have begun addressing with an elevator modernization and rehabilitation contract in Building 37 and major repairs in several others. We have also increased our contract preventive maintenance effort by 50 percent.

Henry Antinarelli, a supervisor in Mechanical Services retired after 32 years of service.

PAUL F. BARRETT

Planning Office

The Planning Office's activities this year featured work on the Institute's five-year plan, a number of school-wide and departmental planning efforts, continued development of our institutional research capability, the preparation of physical planning data and materials in anticipation of the next planning cycle, a number of traffic, transportation and landscape projects on the campus, and continuing efforts to coordinate campus planning with municipal and metropolitan agencies.

Our review of Institute departmental five-year plans included correlating projected levels of space, staff and operating budgets, and preparing analyses of physical and demographic resource requirements as they will affect MIT in the future. As part of this work, an initial effort was made to develop a space utilization plan which should assist in allocating scarce space resources.

Our institutional research efforts focused on the development of an historical database showing space allocations by MIT department from 1967 to the present, the annual update of the ROTC cross-enrollment report, the implementation of a computerized database for tracking utilization of Institute parking resources, and a major study of MIT-related conference activity including various measures of conference volume, available resources, and alternatives which would allow more efficient utilization of Institute staff and space.
In cooperation with the Office of the Provost and the Director of Information Systems, we are continuing the development of a management information system for comprehensive institutional planning. In parallel, we are reviewing all of our physical database and information systems to provide for a coherent and more easily maintainable system of information on MIT's physical resources.

Physical planning activities this year focused on traffic and circulation projects that included the completion of the Massachusetts Avenue Crossing Project Phase II, reorganization of the service traffic arrangements on the East Campus and in Kendall Square, discussion with the MBTA and the state Department of Public Works on the proposed renovation of the Harvard Bridge, MBTA bus service to the MIT campus, and a major analysis of the implication of establishing a parking fee for MIT commuters.

Major physical planning projects this year included the Walker pedestrian way, Eastman and McDermott Courts circulation, East Campus houses landscaping, Millstone Hill forest management plan, relocation of Amherst Alley, Class of 1985 gift, Rotch Library expansion, and East Campus street landscape master plan.

Community planning activities included cooperation with the Cambridge Redevelopment Authority on the continuing development of Kendall Square, the Cambridge Fire Department in a joint effort to evaluate fire service facilities for the Kendall Square and MIT campus area, the Cambridge Planning and Development Department in connection with the Simplex project, and the town of Westford in connection with conservation proposals that have been made for areas bounding on MIT's properties.

The Director of the Planning Office served, this year, as the president of the Society for College and University Planning and the Planning Office staff presented papers on capital budget analysis techniques at the annual conference of the Association for Institutional Research.

O. ROBERT SIMHA

Property Office

In December, the Property section of the Office of Facilities Management Systems was reorganized into an independent department reporting to the Senior Vice President. The Office is responsible for the accounting and asset management of more than 150,000 items of equipment which are both MIT-owned as well as sponsor-owned.

Property Management

During the year, more than 8,000 newly acquired items of moveable equipment were identified and tagged. Over 100,000 purchase orders were reviewed to verify equipment purchases, and 11,000 invoices pertaining to equipment were processed. A biennial inventory of existing items of moveable equipment continued with approximately 85,000 items being identified. A complete inventory of the Institute will be completed by December 31, 1985.

Government Reporting

Over 146 final inventories were submitted to sponsors as part of the closing out of contracts, grants, agreements, etc. There were 254 financial reports prepared and submitted to various government agencies. Also, four retirement reports were prepared and submitted to the sponsor.

Acquisition of Equipment at No Cost

Almost $276,000 (original acquisition cost) of excess Federal government equipment was acquired as well as $11,200 of surplus State equipment. Also, 25 items of new equipment and materials with an approximate value of $4,000 were acquired from the National Association for Exchange of Industrial Resources and distributed to departments having requests on the specific needs list maintained by the Property Office.
Dispositions and Reutilization

Approximately 300 items of equipment with an acquisition value of $37,500 were transferred between MIT departments for reutilization. Equipment, unneeded or unusable by the MIT community was sold for $11,800. Most of the equipment available for reutilization or sale continued to be displayed at the MIT Equipment Exchange.

Property Accounting

The annual indirect cost study for the equipment pool was completed in conjunction with the Comptroller's Office and resulted in a $2.2 million recovery for MIT. Since a new methodology for this pool was developed in 1979, this pool has increased by almost tenfold. Monthly reconciling of the Accounting records with the Property records continued with very positive results.

Database Management

The Property database was maintained using the INSITE 3 database management system. Over 8,000 additions and over 76,000 changes to the database were processed.

Society for Property Administrators

The Society for Property Administrators (SPA) which is administered by the Property Office, conducted a three-day Property Management Conference in Scottsdale, Arizona. More than 125 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.

Storage Facility

The operation of the MIT storage facility at 224 Albany Street (NW30) continued providing short-term storage to 50 departments for the temporary six-month storage needs of the Institute community.

J. TERENCE MEEHAN

Purchasing and Stores

Major projects accomplished or initiated this year include:

1) Standard Institute purchasing procedures were researched and prepared and the "MIT Purchasing Procedures Manual" was distributed to all purchasing personnel and administrative officers. It was also distributed to department heads and laboratory directors of those activities which have separate purchasing agencies assigned to them. Standard written purchasing procedures are necessary to protect the Institute and the sponsors of its research, to comply with the provisions of Institute Federal contracts and grants, and to comply with the recommendations of Institute and Federal audit and procurement review agencies.

2) Representatives of the Office of Naval Research and the Defense Contract Audit Agency conducted the fourth review since 1976 of the Institute's procurement system. The Review Team's report was highly complimentary of the Institute's procurement procedures and practices, and, as a result, the Office of Naval Research provided formal notification that the Institute's "Government Approved Procurement System" was continued.

3) Under agreements negotiated with IBM, Digital Equipment Corporation, and Apple Computer, Inc., MIT students, faculty, and other employees were able to purchase personal computers and accessories for personal use at substantial discounts from the newly established Information Systems Department's Microcomputer Center. The same arrangements and discounts were made available for purchases made on behalf of MIT departments, laboratories, and centers. The Office of Laboratory Supplies provided purchasing and lo-
gist of support to the Microcomputer Center to ensure a manageable and efficient personal computer acquisition/resale/distribution program for Institute and personal purchases.

4) A Purchasing System Project Team was convened by the Director and charged with responsibility for planning, designing, developing, and implementing a fully automated, integrated, on-line purchasing system. The system will be interactive with the existing Accounts Payable automated system, and will allow for the creation, printing, storage, display, and processing of entire purchase orders on-line.

The Project Team coordinated extensively with other administrative offices to ensure the development of as fully an integrated system as possible. A comprehensive Requirements Planning Document has been developed. System design and programming are scheduled to be accomplished during the coming year, and the System is expected to be ready for implementation by the end of the year.

Longer range plans include providing the capability for departments, laboratories, and centers to utilize electronic requisitioning for communicating their requirements to Purchasing and Stores locations and to access selected information from the Purchasing/Accounts Payable System.

5) The Office of Laboratory Supplies commenced the design and development of an automated, on-line Cylinder Control and Billing System. The System will be used to track the receipt, location, and return to vendors of the approximately 8,000 compressed gas and liquid cylinders on campus. In addition, the System will provide for charging user accounts directly for the monthly demurrage (rental) costs they incur in connection with the gases and liquids they utilize, thereby eliminating this expense from Institute overhead. A physical inventory of all cylinders on campus will be performed during July and August and the information gathered will be used in establishing the database for the System. The System is expected to be ready for implementation in September of the coming year. The automated System and billing procedures represent sound business practices which also satisfy the requirements of Institute Federal contracts and grants for the treatment, accounting, and control of such a commodity and its costs.

General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Major emphasis continued to be placed on negotiating discount agreements with suppliers.

Office of Laboratory Supplies

Combined Institute sales of office and laboratory items and furniture and furnishings increased 5 percent over the previous year. Sales of office and laboratory items increased 3 percent and sales of furniture and furnishings increased 13 percent.

The established Office of Laboratory Supplies' systems for purchasing, receiving, storage, inventory control, delivery, coordination with the Property Office, and internal billing were utilized to support the Microcomputer Center's personal computer resale programs.

Minority and Women-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of over $5.5 million to minority and women-owned business concerns. For the first time, the Institute exceeded the $2.5 million level in awards to both minority and women-owned business concerns. Over $2.7 million was awarded to 195 minority businesses and over $2.7 million was awarded to 517 women-owned businesses. Accomplishments this year represent a 22 percent increase over the previous year.

BARRY ROWE
Safety Office

Preparation of material to insure compliance with the new Right to Know Law proved to be a massive undertaking. However, all required material was filed prior to the deadline established in the legislation and we are now well into the implementation phase.

A policy statement on environmental health and safety was issued to all members of the MIT community during the year. This statement represents an expansion and clarification of previous documents on this subject.

Education and Training

Many of the larger departments requested Safety Office assistance in converting their existing informal training efforts to more formal safety training programs. The Emergency Action Plan training program continued throughout the year. A total of 61 plans were submitted to the Safety Office for review and approval.

Laboratory Safety

Laboratory Safety Committees had a very active year. New committees have been formed and older ones expanded. Primary effort of the membership involves improving training programs, reviewing procedures for working with hazardous materials, making laboratory inspections, and investigating accidents.

The demand for safety seminars has increased. Many departments have formalized safety seminars where attendance is required before personnel are allowed to work in the laboratory.

The volume of waste chemicals increased slightly over last year.

Fire Protection

Automatic sprinkler protection was extended to the wind tunnel in Building 33. A separate water supply for fire protection was brought into Baker House in anticipation of installation of sprinklers at a later date. Sprinkler contracts have been awarded to complete work in the Westgate apartments (W85) and Senior House (E2 and E3).

New fire alarm systems were installed in Buildings 20 and W31 and system improvements were made in Buildings E34, W71, and NW14.

A total of 106 fire alarm tests were conducted, 88 of which were associated with residential facilities.

Physical Facilities Review

The major activity involved small space changes where 107 projects were reviewed. In addition, Talbot House renovation plans were reviewed for compliance with Vermont State and Building Officials and Code Administrators (B.O.C.A.) codes.

There were essentially no large facility reviews, although the proposed toxic gas and hydrogen detection and alarm system in the new Microsystems Research Laboratories (Building 39) was reviewed.

Safety Audits

The Physical Plant department, in conjunction with the Safety Office, has set up a Code Compliance program. The program resulted from the City of Cambridge Building Department’s inspection of the campus. Funds have been allocated to correct any deficiencies noted on a systematic basis.
Lincoln Laboratory

The Safety Office at Lincoln Laboratory has recently been given responsibility for the complete control over all phases of Workers' Compensation cases. Previously, the Personnel Office handled the financial aspects of these cases.

The Safety Committee charter and membership have been revised.

A Right to Know instruction program has been developed and is presently being implemented.

Operation and administration of hazardous waste disposal will be assumed by Group 15, the Stock Group. The Safety Office will be available to assist as a resource.

Industrial Accidents

The number of industrial accidents remains constant (very low) and our primary efforts will now be directed toward reducing the severity of accidents.

Personnel

Kathryn Blass joined the staff to coordinate Institute-wide Right to Know programs.

William MacLachlan transferred to Lincoln Laboratory to assume the position of Safety Manager.

Joseph Kuchta retired after 19 years of service to the Institute.

JOHN M. FRESINA
Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory, 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 the User Program for the past year include:

1.) **Exotic Superconductors.** Several remarkable superconducting systems have recently been discovered. A number have been studied at the Laboratory, including heavy Fermion superconductors, magnetic superconductors, and organic superconductors. Much of this work requires the unique combination of high fields and low temperatures that NML provides.

2.) **Continuing Studies of 2D Electron Dynamics.** About ten groups regularly use the high fields at NML to study electron dynamics in two-dimensional semiconductor structures. This topic is now the second most active (after superconductivity) at the Laboratory. Systems studied include: GaAs/(GaAl)As, Si MOSFET’s, InAs/GaSb, graphite, HgTe/CdTe, and InGaAs/GaAs.

3.) **Pulsed Field Facilities.** The Laboratory now provides pulsed fields to users. Instrumentation for the copper coil, 45 T, capacitor-driven system is gradually being improved. Engineering studies of a 70 T, steel-coil system are in progress.

4.) **High Field/Low Temperature Facilities.** The NML low temperature/high field facility is being expanded via acquisition of a second dilution refrigerator. Demand for these facilities remains high. Systems recently investigated in them include: Two-dimensional electron structures, heavy Fermion superconductors, ultra-thin metal films, and diluted magnetic semiconductors.

**SUPERCONDUCTIVITY**

Optimization of commercially fabricated (Nb4 atomic % Ta)3Sn multifilamentary superconducting wire with external tin processing achieved overall critical densities, Jc, of 10^4 A/cm^2 at 19.7 tesla.

Powder metallurgy processing of Cu-Nb-Sn materials using small hydrostatic extrusion showed promise for achieving further increases in J_c for high field applications by using increased Nb content and/or increased Ti additions.

Hydrostatic extrusion processing of powder metallurgy processed Nb-Al was initiated to examine practical fabrication of this high performance superconducting material. A new direction for powder processing involving rapidly quenched powders was initiated with members of the Department of Materials Science and Engineering.

A new basic research program on model thin film Nb/Al bilayers and multilayers was initiated. In addition to leading to a better microscopic understanding of Nb-Al, we expect that this program will point to further improvements of the powder metallurgy processing of Nb-Al.

A Nb3Sn thin film material with a narrow upper critical field transition has been found. High resolution measurements of $H_{c2}(T)$ are being made in the Hybrid magnet in order to test the theories for high field superconductors.

Measurements of the upper critical field in Nb3Sn thin films with small additions of Ga were completed. This superconductor has the highest $H_{c2}$ of any Nb3Sn material with additives.

Measurements of $H_{c2}$ for PbMo6S8 with controlled oxygen content were completed. These very high field superconducting materials are very sensitive to admixtures of oxygen.

A method to examine individual filaments of commercial NbTi high field superconductors was developed in order to evaluate such conductors at high field.

Short lengths of experimental microcomposite strong Nb/Cu wire have been obtained for tests in small pulsed field magnets.
RESEARCH IN THIN FILM SUPERCONDUCTIVITY

UBe$_{13}$ thin films have been made by codeposition for the first time. This heavy fermion material (a material whose effective electron mass can be 100 or 1000 times greater than the free electron mass) is a superconductor below about 1 K and is a candidate for a new kind of superconductivity in which the electrons have p-wave rather than s-wave pairing. The critical magnetic field of these films has been measured and a very strong negative magnetoresistance has been observed in the normal state to magnetic fields of 19 teslas.

Spin polarized tunneling measurements have been successful for the first time in thin films of the elemental transition metal superconductors Nb and V. Zeeman splitting of the density of states has been observed in both instances and will allow determination of spin-orbit scattering in these model systems which are of importance in understanding superconductivity in very high fields.

A new method of measuring the magnetic susceptibility of thin films and submonolayer coatings has been developed. This radio frequency method can detect $10^{-6}$ of a monolayer coverage of Fe on a superconducting Pb substrate. This method is being applied to the detection of magnetic moments of impurities in thin films and the magnetic behavior of surfaces and interfaces.

We have shown that superior films of NbN can be formed by heating Nb films in N$_2$ rather than using reactive sputtering, thereby avoiding the problem of columnar growth.

We have made superconducting films of V$_3$Ga as thin as 60 Å thick and layered films alternating V$_3$Ga and Pt or Ta with a repeat distance of 30 Å. We expect these very thin films to be useful in understanding the high magnetic field properties of V$_3$Ga.

A digital signal processing technique of Fourier analysis, known as cepstral analysis, can be used to measure the Zeeman splitting directly from the total conductance of superconducting tunneling junctions. This technique has also been used to measure the g-factor in V$_3$Ga as well as its energy gap.

Thin films of the Chevrel-Phase superconductor AgMo$_6$S$_8$ have been prepared by simultaneous sputtering of silver and molybdenum onto sapphire substrates held at temperatures between 800°C and 1000°C using H$_2$S as a reactive gas. The best films have a superconducting critical temperature of 9.2 K, a transition width of 0.2 K, and an upper critical field of 13 T at 1.5 K.

Spin-resolved tunneling conductances were measured on thin films of the Pauli-limited superconductor Al which had various surface coverages of Pt. The conductance data shows that the increased Pt coverage results in an increase of the spin mixing, and this data also allows a measurement of the spin-orbit scattering rate and the Fermi-liquid parameter.

LOW TEMPERATURE AND HIGH MAGNETIC FIELDS

Progress was made this year in several areas of experimental low temperature condensed matter physics and in research techniques at very low temperatures and high magnetic fields. Primary research areas presently involve novel physical systems which achieve their most interesting ground state properties under these conditions. Most notable are the following:

1) Observation for the first time by a U.S. group of the fractional quantum Hall effect in a silicon MOSFET device below 0.1 K, thereby establishing the thermal activation of the effect and the fact that fractional behavior is a universal result of the two-dimensional electron gas which is not specific to AlGaAs heterostructures.

2) Determination of the critical field of the heavy Fermion superconductor UBe$_{13}$ at low temperatures. This result supports the suggestion that the nature of the superconducting state in these materials is truly unusual, and that the description of the superconducting state of these materials may involve physical processes outside the context of the well known BCS theory for conventional superconductivity.

3) Success on the first measurements of the magnetization of the two-dimensional electron gas in an organic metal above the Kibble transition, at which point this system undergoes a transition from an open orbit metal to a closed orbit semimetal. These measurements have shed new light on the Fermi surface and thermodynamic nature of the magnetically induced transitions in this system.

4) Completion of the first accurate measurements of the magnetic susceptibility of the Fermi liquid helium-3 in high magnetic fields. Our results indicate that the theoretically predicted eventual nonlinear behavior of the susceptibility lies outside the present limits of high magnetic field and low temperature technology, but set standards for the ultimate successful investigation of this fundamental problem.
5) Identification and characterization of CePb$_3$ as a new heavy Fermion system which has an antiferromagnetic ordering and a possible field induced re-entrant high magnetic field superconducting state. Measurements of the heat capacity are presently underway to investigate the bulk nature of this high field transition.

6) First observation of the high magnetic field magnetization of heavy Fermion superconductors in the class U$_x$Th$_{1-x}$Be$_{13}$ to 17 T below $T_c$. These results allow an investigation of the mixed state where resistivity measurements are insensitive, and where the competition of different forms of the superconducting state may exist. Indeed, an anomalous paramagnetic signal below $H_c$ has been observed, and these effects are being actively pursued. The high magnetic field susceptibility, which is observed to be field independent, bears a close relation to the helium-3 problem in that both systems are Fermi liquids. The eventual observation of nonlinear behavior in either system at very high fields should prove most interesting.

7) Funding has been obtained from the National Science Foundation to upgrade the Low Temperature High Magnetic Field Facility. A new top loading dilution refrigerator has been ordered (to arrive, December 1985), a nuclear orientation thermometry system is being installed, and plans to improve the physical laboratory design have been approved and will be executed in August 1985.

SEMICONDUCTORS

An anti-crossing, predicted by People and Wolff, was observed between Zeeman-split $1s(T_2)$ states of opposite spin for As donors in germanium, via four-wave spectroscopy with CO$_2$ lasers.

Stress-induced electric dipole spin resonance contribution to the second-order nonlinearity in n-type lnSb was studied via far-infrared generation at the difference-frequencies of CO$_2$ laser lines.

New results have been obtained for the problem of an electron confined to two dimensions, in a magnetic field, and interacting with a LO phonon field. A path integral theory believed heretofore to produce an upper bound to the true ground state energy was shown to give, in fact, energies lying below the exact ground state energy in high magnetic fields. Fourth order perturbation theory for the ground state of the electron, heretofore considered too difficult to calculate, has been evaluated employing a novel method.

SEMIMAGNETIC SEMICONDUCTORS

Investigations of quantum wells in semiconductors, semimagnetic semiconductors, and classical semiconductors have been carried out.

The antiferromagnetic exchange constant between nearest neighbor Mn$^{++}$ ions in the semimagnetic semiconductor Cd$_{0.95}$Mn$_{0.05}$Te was determined to be $7.7 \pm 0.3$ K, using optical measurements of the free exciton splittings in high magnetic fields.

Temperature dependence of the infrared electroluminescence from Hg$_{0.88}$Mn$_{0.12}$Te p-n junction was studied over the range from 5.4 K to 300 K. The total luminescence intensity showed a broad maximum around 70 K.

The exchange interaction between semiconductor carriers and the magnetic ions has been studied in semimagnetic semiconductors like (Cd,Mn)Te, (Cd,Mn)Se and (Zn,Mn)Te. High magnetic fields are used with photoluminescence, Raman scattering and nonlinear optics.

Multiple quantum well structures made from (Cd,Mn)Te, (Zn,Mn)Se and (Ga,Al)As have also been studied with optical and transport methods.

Methods of determining the distribution of magnetic ions, and the exchange interactions between these ions, in dilute magnetic materials have been developed. They are based on the newly discovered phenomenon of magnetization steps at high magnetic fields and on traditional susceptibility measurements. These techniques have been successfully applied to several II-VI dilute magnetic semiconductors, and are now being applied to a new class of dilute magnetic semiconductors with the chalcopyrite structure.

The effect of the s-d interaction on the metal-insulator transition has been studied in the dilute magnetic semiconductor Cd$_{1-x}$Mn$_x$Se. Samples which are just on the metallic side of the transition at zero magnetic field were found to exhibit an insulating behavior at moderate magnetic fields. A preliminary model which accounts for these observations was developed.

A publication on the observation of a new collective excitonic state in multiple quantum wells (MQW) has been accepted. Experimental observations and theoretical interpretation on two-dimensional electron-hole plasmas and Zeeman effects in quantum wells have been performed. Quantized Thomas-Fermi shielding of excitons in modulated doped MQW has been observed in magnetic fields.

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**IR Photovoltaic Detectors Utilizing HgMnTe and HgCdMnTe Semimagnetic Alloys** - The preparation and performance of photovoltaic infrared detectors made from HgMnTe and HgCdMnTe semimagnetic alloys have been studied. HgMnTe and HgCdMnTe crystals were grown by the Bridgman method and by isothermal vapor phase epitaxy, respectively. The presence of Mn chalcogenides resulted not only in a higher energy gap, but also in a lower series resistivity than those of HgCdTe. Junctions were made by annealing p-type samples cut from as-grown material in a Hg-plasma atmosphere. The junctions exhibited very good I-V characteristics, in many cases far superior to those of the junctions made in HgCdTe crystals. By controlling the Cd and Mn content the peak photoresponse of these detectors was varied from 1.2 to 12 μm at 77 K. The sensitivity and detectivity of the detectors compare favorably with those of good quality HgCdTe photovoltaic detectors. The measured detectivities are $1.5 \times 10^{11}$ and $4.6 \times 10^{10} \text{cmHz}^2\text{W}^{-1}$ for detectors with a photoresponse peak of 4.6 and 10.6 μm, respectively. Low temperature measurements of the electrical properties of these junctions in high magnetic fields have revealed new features which we attribute to the exchange interaction between the spins of the localized Mn electrons and the spins of the band electrons.

**Comparison of the Properties of CdMnTe Crystals Grown by Different Techniques** - A systematic study of the growth CdMnTe materials has been undertaken. The goals of this work are to investigate the effects of the growth processes, such as temperature gradient and equilibrium vapor pressure, on the crystalline morphology, radial and axial compositional homogeneity, distribution of impurities, and crystalline defect formation. Crystals grown using the Bridgman/Stockbarger technique, the traveling heater method, and by liquid phase epitaxy have been examined using the techniques of X-ray diffraction, microprobe analysis, transmission electron microscopy, cathodoluminescence, photoluminescence, optical absorption, Hall effect and resistivity measurements. Preliminary results have demonstrated the superiority of liquid phase epitaxy and the traveling heater method for producing material with improved compositional homogeneity, and crystalline morphology. The materials grown by these methods allow improved control of impurity segregation, as well as a reduction in the defect density. However, the Bridgman/Stockbarger method still provides significantly higher growth rates and larger grain sizes.

**The Magnetic Field Influence on the Photovoltaic Effect in Mn Alloyed Semiconductors** - The exchange interaction between band electrons and the 3d5 electrons of Mn2++ ions in semimagnetic semiconductors such as HgMnTe and HgCdMnTe, makes the band structure of these materials highly dependent on the alloy composition and external magnetic fields. Observations of electrical and photoelectrical properties of p-n junctions made in ternary HgMnTe and quaternary HgCdMnTe alloys, as a function of Mn concentration and external magnetic field have been made. The measurements determine important band parameters.

The observations confirm a high negative magnetoresistivity in the HgCdMnTe alloys; the highest was found in the ternary HgMnTe compounds. It was found that this effect strongly modified the I-V characteristics and the photovoltaic spectral response of the p-n junctions. The junctions dominated by diffusion currents also became tunneling junctions at high magnetic fields.

Using photovoltaic measurements on the p-n junctions in a magnetic field, the interband, F8-G transition can be characterized as a function of magnetic field. Measurements of these interband photovoltaic oscillations lead to a determination of the energy gap and its magnetic field dependence, plus the average Landau and spin splitting in the ternary and quaternary alloys.

**LIQUID CRYSTALS**

A lyotropic liquid crystal was investigated on both sides of a nearly second order nematic-isotropic phase transition. Analyses in terms of a Landau theory, as well as an N=5 critical N-vector model, were performed, and the order parameter was shown to be non-separable (into modulus and directional parts). In addition, a strong concentration dependence was found for the micelle configuration.

**NUCLEAR MAGNETIC RESONANCE**

Beginning in 1982, the Laboratory with support from IBM has been engaged in a collaborative research project on the development of advanced instrumentation for magnetic resonance imaging of the human body. The task is to develop three high homogeneity superconducting magnet systems, advanced electronic consoles and software for image data acquisition, reconstruction and analysis. Two complete systems will be placed in operation at the Brigham and Women's Hospital, a teaching hospital of the Harvard Medical School. The third unit will be retained at the Laboratory and be part of the instrument complement of a Magnetic Resonance Imaging (MRI) Facility housed in a new 13,000 sq. ft. laboratory especially designed for magnetic resonance imaging. This research facility will be used by investigators from the local biomedical community and the Whitaker College at MIT. The new site has been occupied since September 1984. A 1.5 tesla, 60 cm warm bore magnet system has been built, installed, and energized. It is undergoing final test and shimming to achieve the design homogeneity of 5 ppm over 25 cm. A 1.5 tesla, 120 cm warm bore magnet, suitable for whole body human imaging and in vivo spectroscopy, has been wound and is in the final stage of assembly prior to placement in a low loss cryostat. The design homogeneity for this system is 4 ppm over 50 cm. An imaging console has been designed, built, and interfaced to a 0.5 tesla/100 cm magnet at the University of California, Berkeley (an IBM test
site). This unit, using our software, has produced state of the art images of the human brain. Siemens Medical Systems, Inc. intends to donate a 2 tesla, whole body imaging apparatus to the Institute. This will be placed in operation at the MRI Facility and serve to initiate a program of clinical imaging research by year end 1985. Plans are also underway to place into operation a 4.7 tesla, 33 cm bore imaging/in-vivo spectroscopy system to be used for animal research.

SOLID STATE NMR

In collaboration with groups from Harvard Medical School, Berkeley, and Leiden, the solid state NMR group investigated $^{13}$C and $^{15}$N magic angle sample spinning (M ASS) NMR spectra of fourteen different $^{13}$C-labeled retinals incorporated into bacteriopsin (to form bacteriorhodopsin (bR)), and $^{15}$N-lys-bR prepared by incubating bacteria with $\epsilon$-$^{15}$N-Lys. The goal of these studies was to elucidate the conformation of retinal in bR. Some of the new features that emerged from these investigations were: (1) $^{13}$C-5 spectra indicated that bR contains a 6-s-trans chromophore and the $^{13}$C-5 shift tensor elements were consistent with the presence of a neighboring electrostatic perturbation, (2) Dark-adapted bR containing a mixture of 13-cis and all-trans retinal and the C=N bond is syn and anti in these two retinals, respectively, and (3) $^{15}$N MASS spectra indicated the Schiff base was protonated and weakly hydrogen bonded to its counterion. The success of these experiments suggests that MASS experiments should be generally applicable to large proteins which cannot be studied with conventional "solution" NMR techniques.

Investigations of the dynamic structure of amino acid sidechains and lipids in biological systems were studied. $^2$H was incorporated into a number of sidechains and the spectra examined as a function of temperature to study the mechanism and the rate of the molecular motion. With this approach it was determined that aromatic rings in a number of solids execute twofold flips at rates varying between $10^3$-$10^7$ sec$^{-1}$.

New types of NMR methodology being developed include methods for extracting rate data from powder line-shapes and MASS spectra and methods for understanding and developing new MASS experiments such as chemical shift scaling, side-band suppression techniques, and bond distance measurements.

MAGNET TECHNOLOGY

In the course of the High Field Short Pulse Magnet Development Program, the first 50 T short pulse magnet was built and successfully tested. The helical magnet was constructed by machining a 5" diameter maraging steel (with ultimate strength of 2000 MPa) bar. The inner bore of the coil has a diameter of 34mm. The first tests of the magnet system and its power source (250 kJ, 20 kV capacitor bank built for MIT by Maxwell Laboratories, Inc.) produced a maximum field of 49.7 T at a charging voltage of 19.2 kV and a peak circuit current of 347.5 kA. The pulse time (half period) was 157 ps, with a rise rise time to peak of 63.5 us. A new method of machining - wire EDM (electrical discharge machining) is being currently explored with a goal of improving the topological properties of coils and creating the possibility of constructing a composite coil including a material with good conductivity and a material with high ultimate strength.

The past two years have been by far the best, most failure-free ever for our resistive, non-hybrid magnets. Exceptional care in their assembly, coupled with preventive maintenance, through the timely refurbishing of coils, have slashed the number of burnouts to a mere five per year.

APPLIED MAGNETISM

Fundamental studies of a new continuous magnetic particle separation technique under NSF funding have produced separators with applications in biological cell sorting important for immune reaction studies, diagnostics and therapy. With DOE support, new work on magnetic conversion of pyrite by selective microwave heating has led to improved high gradient magnetic desulfurization of coal, important for acid rain control and the utilization of U.S. energy resources.

MAGNETISM IN LIVING SYSTEMS

Mammalian ferritin, an important iron-storage protein containing up to 4000 iron atoms per molecule, was found to be reducible up to one electron per iron atom without loss of iron. During reduction, the molecule takes up two protons from the external medium per electron. Thus ferritin could function in cellular electron and proton storage as well as iron storage.

Magnetotactic algae have been discovered in a mangrove swamp near the equator in Brazil. Electron microscopy revealed that each cell contains thousands of single magnetic domain Fe$_3$O$_4$ particles. This is the first instance of a connection between magnetite and magnetotaxis in a eukaryotic organism.

The Low-Field Group continues to study the magnetic field produced by the human brain. These MEG (magnetoencephalogram) measurements have had their most direct application in localizing the exact source of the problem in the brain of an epileptic patient. They are also applied in localizing the
exact sources of other electrical events in the brain; the electroencephalogram (EEG) is not good in these localizations.

Measurements of magnetoencephalograms and electroencephalograms from somatosensory sources in the rabbit brain have been made; these measurements will provide a foundation for a better understanding of these measurements in humans. Theoretical and computer modeling studies of "moving dipole" solutions to the problem of localizing electrical sources in the brain have been performed.

PETER A. WOLFF
Center for Materials Science and Engineering

The Center for Materials Science and Engineering (CMSE) was founded in 1960 for the study of the structure and properties of materials. Major funding for the Center programs is provided by the National Science Foundation (NSF) under the Materials Research Laboratory program. The Center operates central facilities which provide state of the art instrumentation and the expertise of professional staff to foster research projects and enhance funding opportunities by the materials community at MIT. Major items acquired this year include a Cambridge Stereoscan Mark III scanning electron microscope, a JEOL 200CX transmission electron microscope, and a Perkin Elmer SIMS II secondary ion mass spectrometer. A new facility for the processing of materials by the technique of rapid solidification was established and substantially equipped during the year. A directory listing our central facilities, their capabilities, and how to use them is available from the Center administrative headquarters.

The CMSE also funded 41 research projects carried out by 37 MIT faculty from the Departments of Chemical Engineering, Chemistry, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics. These were collaborative research on major problems in materials research. Organized into several areas of thrust, this is research of a kind difficult to fund through direct grants from a funding agency to a single investigator.

An important part of our research program was the seed funding provided to five projects for faculty seeking to develop exciting new ideas which can either be incorporated into one of our areas of thrust or receive continuing support from other sources. We also provided seed funding for a group initiative with the goal of producing high performance specialty steels; this effort will become a new thrust area next year.

Our weekly colloquium on a wide range of topics in materials research was held during the academic year, and we provided support to two seminar series, one in polymer research and one in condensed matter physics. The central facilities offered several training courses during Independent Activities Period as well as at appropriate times during the school year.

Below, we briefly outline the research activities of our thrust areas during the past year. The names and departmental affiliation of the individual researchers are given. This was the final year of a three year grant from the NSF. A proposal for the next three year period was prepared and submitted to the NSF; we were examined by a site visiting team in the late summer of 1984 and our proposal has been funded for the next three years with a substantial increase (38 percent) in support.

Research on Flow and Fracture in High Temperature Alloys

This work consists of a number of interrelated studies on nickel-base high temperature alloys of the kind used for turbine blades in jet engines. Major effort has been directed towards elucidating the mechanisms for creep deformation.

A bimodal distribution of coarse and fine precipitated particles was produced by prolonged isothermal aging before cooling the alloy Astroloy to the creep temperature range of 700 Celsius. This alloy had improved creep resistance and ductility, but fractured along grain boundaries; the same techniques will be used on single crystal materials. A thermomechanical treatment that includes the addition of room temperature plastic strain has been found to produce a unique banded microstructure which may lead to improved creep resistance as well as fundamental insight into the role of dislocations in stress coarsening. Computer simulation of the process is being developed concurrently. Studies of oxide dispersion strengthened (ODS) alloys, such as Inconel 718, show that thermomechanical processing that involves recrystallization of material rolled during the initial consolidation of powder constituents is a promising way to increase their creep resistance. A computerized dc potential drop system has been developed to monitor the deformation and crack formation in notched bars during creep rupture tests. Early results show that a circular notch fails by cavitation, while a British standard notch fails through the formation of a single crack.

Gas turbine blades are commonly protected against oxidation and hot corrosion by a 60-100 micron coating of aluminide. Experiments in the thrust area this year indicate that thermal fatigue resulting from repeated heating and cooling is the chief reason for the coating to fail. Various temperature and strain histories are being tested to see which produce the kinds of failure observed in service, and equations are being developed to model the behavior.

Apparatus to study the compression of iron-base ODS alloys under constant strain rates has been put into operation, and shows that deformation mechanisms are rate dependent. It will also be used for tension-torsion measurements, and the resulting data will be used to formulate macroscopic continuum constitutive equations.

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Faculty/Department: Professors Samuel Allen, Nicholas Grant, Regis Pelloux (Materials Science and Engineering); Lalit Anand, Ali Argon, and Frank McClintock (Mechanical Engineering).

Structure and Properties of Microcrystalline and Glassy Alloys Produced by Rapid Solidification

Amorphous and microcrystalline materials produced by rapid cooling promise to be of technological and economic importance. There are now about 20 faculty members and a group of 35 to 40 staff and graduate students involved in producing and studying metastable glassy and microcrystalline materials produced by rapid solidification (RS). Research of this kind was initiated at MIT about 15 years ago under CMSE sponsorship. It is now successful and well funded. We decided that the most effective use of the limited resources available to CMSE would be to discontinue the thrust area and to establish a central facility for RS processing that could benefit all members of this large and active group.

Faculty/Department: Professors Nicholas Grant, Keith Johnson, Ronald Latanision, and John Vander Sande (Materials Science and Engineering).

Catalytic Activity and Surface Structure

The basic research programs in this thrust area have focussed on the understanding of how local environment can influence electronic structure and catalytic activity.

The interaction of molecular beams with clean surfaces in high vacuum has been used to study the effects of surface structure on the first step of a chemical reaction. This includes the dissociative absorption of CO₂ and CO on Ni and Pd. Experiments carried out this year showed direct evidence for a precursor molecule during chemisorption of CO on Ni as well as the first observation of an energy barrier to molecular chemisorption. Molecular dynamics calculations of the absorption process will be done using an empirically derived interaction potential; the current effort is a search for a potential energy surface which can reproduce all the observed characteristics and maintain calculational tractability.

Work has also continued on the use of various forms of supported Pd to catalyse the electrolytic reduction of CO₃H₂ to HCO₂. The effects of temperature and added electrolyte have been studied. Infrared spectroscopic studies have also revealed why other noble metals, particularly Pt, are not effective; it appears that Pt-CO is formed and the reaction to reduce the aqueous CO₂ is blocked by inert surface carbonyl species.

Faculty/Department: Professors Keith Johnson (Materials Science and Engineering), Sylvia Ceyer, Robert Silbey, and Mark Wrighton (Chemistry).

Defects in Solids

In preparation for the renewal proposal to the NSF, activity in this thrust area has been more tightly focussed to study defects in semiconductors rather than all electronic and electro-optic materials. Materials are grown, studied experimentally, and microscopic theories of the properties are formulated, all within the thrust area.

Using a molecular beam epitaxy (MBE) system, high mobility doped and undoped GaAs and AlGaAs epilayers have been grown on GaAs substrates. Silicon doping, n-type, has produced materials with liquid nitrogen mobilities as high as 22,000 cm²/Vsec, an excellent value. A low pressure chemical vapor deposition (CVD) process has been developed which enables the deposition of silicon epitaxial films at temperatures as low as 650 C. This is the lowest silicon epitaxial deposition temperature ever reported for a thermally driven CVD process.

A transient electric field effect technique has been applied to study the electronic structure of amorphous As₃S₃. The data are useful complements to the results of time dependent photoluminescence (PL) experiments in the same material which suggest the PL center behaves like a self-trapped exciton. This is an interesting result since it could lead to the formation of defects that might explain phenomena such as the photodiffusion of silver and photo-crystallization.

A calculation based on local density function theory and non-local pseudopotential theory has predicted a positive correlation energy for defects in homopolar chalcogenide glasses, e.g. selenium. This unexpected result has been confirmed by a careful reexamination of experimental results. Substantial progress has been made on a Monte Carlo calculation of the properties of a two-dimensional Coulomb glass; it appears that the Coulomb glass behaves just like a spin glass. These results are important for understanding semiconductors with a high density of defects.

Faculty/Department: Professors Dmitiri Antoniadis, Clifton Fonstad, Rafael Reif, Stephen Senturia (Electrical Engineering and Computer Science); John Joannopoulos, Marc Kastner, Patrick Lee (Physics); and Harry Tuller (Materials Science and Engineering).
Phase Transitions

The goals of this thrust area are to use state of the art experimental tools in combination with modern concepts in statistical mechanics to understand on a very fundamental basis the kinds of phases which can exist in nature and their properties. In the past year the synchrotron radiation program was made into a central facility; it will be of special importance to the experimental work in this thrust area.

Work has continued using a combination of high resolution x-ray scattering, light scattering, and precision calorimetry to study phase transitions in smectic liquid crystal mixtures. These experiments showed the unexpected result that the smectic density wave becomes decorrelated when the smectic short-range order changes from smectic A in character to smectic C like near the nematic/smectic A/smectic C multicritical point. This sheds a new and interesting light on the behavior of systems with competing order parameters.

The coil-globule transition in polymer chains is fundamental to understand conformation changes of large molecules in solution. Light scattering experiments have been carried out which show that this transition can be quantitatively understood using the theory developed for critical behavior in fluids if it is modified for the finite size of the system.

Members of the thrust area have recently begun to extend their interest to microemulsions and ordered phases of surfactants. These seem likely to be elucidated by the tools used by the groups and preliminary light and neutron scattering experiments have been done.

Theoretical work on the statistical mechanics of a lattice of a mixture of prolate and oblate molecules have produced interesting results that may be relevant to micellar phases as well as biaxial order in liquid crystal materials.

Faculty/Department: Professors Carl Garland (Chemistry); Sow-Hsin Chen (Nuclear Engineering); Robert Birgeneau, Thomas Greytak, George Benedek, Nihat Berker, David Litster, and Toyoichi Tanaka (Physics).

Deformation and Fracture in Polymer Composites

An understanding of the micro-structural causes and mechanisms of toughness in polymers is one of the main goals of this thrust area. Another goal is to apply modern techniques in heterogeneous catalysis to obtain better control over the synthesis and microscopic properties of polymer materials. Polymers have also been used as supports for catalysts in electrocatalysis.

There has been considerable work on the role of nucleation and growth of crazes in the deformation of polymer materials. Experiments on the shapes of hysteresis loops combined with electron microscope studies at several locations of the loop are generally consistent with a picture of solid matter being converted into crazes through the nucleation and spread of crazes from particles.

Experiments on films of benzylviologen polymer on a gold surface have shown thickness changes of as much as 50 percent as the redox level changes. This coupling between geometric and electronic structure is also under theoretical investigation. It may have practical implications for devices to convert electrical signals to mechanical ones, and is related to work carried on in the phase transition thrust area.

Faculty/Department: Professors Ali Argon (Mechanical Engineering); Robert Cohen, Ulrich Suter (Chemical Engineering); Mildred Dresselhaus (Electrical Engineering and Computer Science); and Richard Schrock (Chemistry).

J. DAVID LITSTER
Significant legislation and National Institutes of Health (NIH) policy impacting on biomedical research are beginning to exert their influence on animal related research in the Commonwealth of Massachusetts. During the last year, under the auspices of new Commonwealth legislation, the Commissioner of Public Health's designees (MSPCA and ARL) have begun routine visits to animal care and use facilities to monitor animal experimentation. The NIH guidelines (to become effective in November 1985) require the MIT Animal Care Committee to review and approve all animal research protocols. The Institute Animal Care Committee has implemented institutional policies for protocol review of animal experimentation and, with appointment of a committee member who is not affiliated with the Institute, will be in full compliance with the new guidelines. During the next year it is intended to have the protocol files completely computerized to achieve easy, rapid, and accurate retrieval and management of ongoing research projects.

The Division of Comparative Medicine (DCM) now manages a centralized animal resource program totaling approximately 80,000 square feet. The new Whitehead animal research facility of 16,000 square feet, occupied since July 1984, is the latest unit under DCM management and direction. The substandard E10 animal care facility is no longer included as a satellite facility. A visit by the American Association for Accreditation of Laboratory Animal Care in 1984 continued the Institute's full accreditation status. The Division is in the process of upgrading and expanding its computer system. The computerization of DCM's administrative records of animal census and billing will soon be enhanced by an animal purchasing program.

Animal-related research at the Institute has been active and growing during the past year; the Division provided some 15 different species of laboratory animals for the research community, and the average daily population has increased from 7,000 to 13,000 during the year. Research activities within the Division itself continue to flourish. The competitive NIH renewal for the Division's regional animal research and diagnostic laboratory was approved and funded for an additional five years. This program is one of 12 laboratories throughout the United States supported by NIH to provide diagnostic services for animals utilized in biomedical research and to conduct research in laboratory animal and comparative medicine. Extramural support for the Division consists of six NIH grants for which DCM staff members are either principal investigator or co-principal investigator, a Veterans Administration contract, and monies derived from Boston-based biomedical research institutions that utilize our diagnostic laboratory facilities.

DCM has recently recruited a virologist to augment our research and diagnostic capabilities. The postdoctoral training program for graduate veterinarians in comparative medicine is achieving national recognition and is attracting outstanding candidates. The Division also has appointed three individuals who are participating in DCM research programs as Visiting Scientists.

During 1984-85, 15 articles were published by DCM faculty and staff. The Division also has published 14 abstracts during the past year, and has presented numerous papers at both national and international symposia on comparative medicine.
The main purpose of the Energy Laboratory is to encourage problem-oriented research on a broad range of energy issues through the interactive participation of people drawn from most of MIT's academic departments. The greatest single research emphasis is the efficient, economic, and socially responsible use of increasingly "dirty" fossil fuels such as coal, tars, heavy crudes, and shale. Specific projects focus on combustion in furnaces and engines, health effects of emissions, energy supply and demand, and conversion to clean fuels. In addition to that work, Laboratory programs include research on conservation, renewable energy sources, nuclear energy, and conventional oil and gas in both technological and economic/policy projects.

Operating expenses of the Energy Laboratory during fiscal 1985 were about $11 million compared to $9.3 million in 1984. The large funding cuts experienced during 1981-1983 appear to be over and we are growing at an encouraging rate. Our sponsorship is now highly diversified with about half of fiscal 1985 funding coming from the private sector (more than one hundred organizations in eleven countries) and about one quarter from the US Department of Energy; at one time DOE provided more than 60 percent of our support. About 60 faculty plus graduate and undergraduate students from 14 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 academic participation helps to weave our activities as closely as possible into the educational fabric at MIT.

Several changes in Energy Laboratory management were announced during the year. Professor David C. White and Dr. Malcolm A. Weiss were both named Co-Directors of the Laboratory; previously they were Director and Deputy Director respectively. The new titles were intended to reflect more accurately how Laboratory activities had been directed for some time. Professor Kent F. Hansen of the Department of Nuclear Engineering was appointed an Associate Director of the Laboratory, replacing Professor Thomas H. Lee who was named the new director of the International Institute for Applied Systems Analysis in Vienna.

Several new programs started during the year. The largest involved MIT and the Idaho National Engineering Laboratory (INEL) in a multi-year program of research in energy-related engineering. The program, funded by the Office of Energy Research of the US Department of Energy (DOE), provides for a broad collaboration between researchers at MIT and INEL. Seventeen projects are under way initially, eleven at MIT and six at INEL, grouped in four research areas. The MIT portion of the program is administered by the Energy Laboratory and headed by Professor Kent F. Hansen of the Department of Nuclear Engineering. Eighteen faculty members and twenty-one graduate students from six departments in the School of Engineering are participating in the MIT projects.

Another joint effort began when MIT and Pennsylvania State University announced the establishment of the Center for Innovative Mining Systems and Equipment. The Center's administration at MIT is being handled by the Energy Laboratory. Through the Center, the two institutions will cooperate on research and education to improve productivity, safety, and environmental management in the mining and mineral industries. Initial focus is on underground coal mining. A steering committee of three faculty members from each institution will direct the work; the committee's first chairman is Professor Carl R. Peterson of the Department of Mechanical Engineering.

A five-year research program on the use of ceramics in internal combustion engines began in the Energy Laboratory involving the Sloan Automotive Laboratory, the Materials Processing Center, and the Finite Element Analysis Group of the Department of Mechanical Engineering. The total program will be supported by a consortium of industry and government sponsors. The research will focus on identifying potential benefits resulting from the use of ceramics in engines, and on developing appropriate materials, diagnostics, and analytical techniques. Dr. Jack A. Ekchian of the Energy Laboratory is directing the program. Another multisponsor study began, this one in the Center for Energy Policy Research. The study, headed by Mr. Loren C. Cox of the Energy Laboratory, is a policy analysis of the international natural gas trade. It covers the major consuming markets of North America, Japan, and Western Europe and includes supply, demand, and producer strategies. Twenty organizations, public and private, US and foreign, are supporting the research.

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 three categories:
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. Beer, 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 the comminution of energy minerals, slurry rheology, generation of hydrogen, and dissociative adsorption of small molecules. (Dr. Malcolm A. Weiss, Director)

The Transportation Propulsion program conducts research on both improving existing engines and developing new concepts. Activities are based in the Sloan Automotive Laboratory and include fundamental and applied research relevant to internal combustion engines, work on alternative propulsion concepts, and policy and technology studies. (Professor John B. Heywood, Program Director; Dr. Jack A. Ekchian, 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 broadband antireflective coatings. (Dr. John S. Haggerty, Program Director)

The Energy Markets, Pricing, and Regulation program conducts research on the structure and regulation of the energy industries and markets, and the interaction between energy markets and the macroeconomy. Current research focuses on the structure and regulation of the US electric utility and natural gas industries; income distribution, productivity, and economic growth effects of changing energy prices; and energy use and conservation. New research directions include economic/financial studies of primary resource firms and of large-scale energy technology investments. (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 international 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 professional staff members from the Energy Laboratory and faculty and students from several MIT departments (particularly the Sloan School of Management and the Department of Economics) and specialists from the Center's Associates. (Mr. Loren C. Cox, Director)

The International Energy Studies program conducts research on economic, political, and security aspects of international trade in fossil and nuclear fuels. Research also focuses on natural resource development, including resource assessment, contracting and investment issues, and markets. Research on developing countries includes these topics as well as debt issues and reciprocal relationships between energy and economic development. New research directions include roles of state enterprises and impacts of technological change and technology transfer on world energy markets.

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 14 utilities; 11 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 fuel resources; and 3) to develop and communicate information that will contribute to public understanding of nuclear power. (Professor Norman C. Rasmussen, Program Director)

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

The Center for Innovative Mining Systems conducts a research program emphasizing underground coal mining. It is concerned with the development of simplified systems suitable for remote control and, thereby, the removal of 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 retrofitted with insulation, heat loss from building foundations, and the insulating value and aging characteristics of closed-cell foam insulation. (Dr. Leon R. Glicksman, Program Director)

The Northeast Residential Experiment Station was established to evaluate the design, performance, and economics of solar photovoltaic (PV) systems. Research is conducted in the area of PV generation systems, interaction of PV systems with electric grids, measurements and instrumentation for PV systems, and system design for a variety of uses. (Dr. Edward C. Kern, Jr., Head)

PUBLICATIONS

During the past year, Energy Laboratory research resulted in 24 technical reports, 13 working papers, and about 60 other publications (journal articles, workshop and conference presentations, etc.) Energy Laboratory Headquarters has available a list of reports and working papers published since 1979 as well as copies of Project Summaries and e-lab.

MALCOLM A. WEISS
During the past year the Nuclear Reactor Laboratory (NRL) engaged in joint activities with nine academic departments and interdepartmental laboratories, the Charles Stark Draper Laboratory, and 19 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, nuclear materials research and development, radiochemistry and trace analysis applied to health effects of coal use, nutrition studies, earth and planetary sciences, nuclear medicine, reactor engineering, computer control of reactors, and training in reactor operations.

NEUTRON SCATTERING RESEARCH

Professor Clifford G. Shull and his Physics Department group have continued their studies on the fundamental wave properties of thermal neutrons and the diffraction physics of neutrons in crystals. Present-day interest in the possible existence of magnetic monopoles (isolated magnetic charges) has led the group to consider the question of magnetic neutrality of the neutron or, equivalently, the degree of magnetic imbalance between the magnetic poles of the known magnetic dipole moment. An experiment has been designed and carried out which has led to an upper limit of $10^{-17}$ for the fractional imbalance of the separated poles, which represents about six orders of magnitude increase in sensitivity over that available from previous observations. In this experiment, the anomalously low effective mass of diffracting neutrons in a crystal is exploited in searching for trajectory deflections with an applied homogeneous magnetic field. Studies have continued on the coherence characteristics of neutrons while traversing a two-crystal interferometer system. The action of phase-retarding edges and refracting prisms on neutrons passing through a limiting slit placed inside the interferometer has been studied. These observations are compared with calculations of wave-mechanical effects and lead to fundamental conclusions concerning the coherence characteristics of the neutron wave packets. Theoretical studies have continued on the possible existence of a neutron-spin Pendellösung resonance effect in crystals in which the Larmor spin precession length is matched to the Pendellösung length in the crystal. An experiment to test this effect is being designed.

NUCLEAR MATERIALS RESEARCH AND DEVELOPMENT

A major alloy development project for fusion reactor first wall materials was continued for the seventh year. This research is directed by Professor Nicholas J. Grant, of the Department of Materials Science and Engineering, and Professor Otto K. Harling, director of the NRL. Professor Linn W. Hobbs, of the Department of Materials Science and Engineering, also participated in the project. Senior research staff included Drs. Janez Megusar and Gordon Kohse. One graduate student completed his Ph.D. dissertation, and several others are currently doing their research on this project. More than 50 journal articles and formal reports have been completed to date as a result of project activities. A major thrust of this research effort has been the exploration of the use of innovative alloy processing techniques, such as rapid solidification from the melt, for the purpose of developing primary first wall alloys for fusion reactor first wall applications. The development of improved first wall alloys is on the critical path toward economical fusion power. The MIT approach provides a means to manipulate alloy microstructure and microchemistry in order to benefit irradiation performance. Alloy design, alloy production, irradiation testing, and postirradiation characterization are the major parts of this interdisciplinary project. Important results from the program included a model for irradiation performance of Ti and C containing austenitic stainless steels and successful testing of highly irradiated (~40 dpa) miniature alloy specimens using a miniature tensile test developed at the NRL. Emphasis in this project has shifted from austenitic stainless steels to ferritic steels and high performance copper alloys. The ferritic materials are inherently more resistant to radiation-induced void swelling but are susceptible to hydrogen embrittlement and exhibit a ductile-to-brittle transformation which after irradiation can shift to the normal operating temperature range. Major emphasis is being placed on improving the ductile-to-brittle transformation temperature by alloy design. Characterization of materials from a major irradiation experiment on high performance copper alloys is proceeding on schedule. This experiment is expected to provide, for the first time, information on the irradiation performance of copper alloys at service temperatures and for significant neutron doses. Significant progress was also achieved in the development of a new miniature specimen test for the determination of the ductile-to-brittle transition temperature. Graduate students involved in all phases of alloy design, production, and testing obtained unique research experience in radioactive materials research.

RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey and research collaborators utilize the MTR-II for neutron activation analysis of geologic materials. The activation analysis laboratory operated by Professor Frey and Dr. Pillamarri Ila was utilized by 10 graduate students doing thesis research in the Department of Earth, Atmospheric and Planetary Sciences and by visiting scientists from foreign countries and other New England universities.
During the past year MIT-based research has used geochemical studies to understand how volcanoes evolve and to define the compositions of the materials melted to form lavas in various geologic environments. A complementary geochemical study has focused on mantle-rocks which formed at depths below the earth's crust. The results can be used directly to understand processes occurring at 50-100 km depth, a region where partial melts segregate from their source materials.

In the same department, Professor M. Gene Simmons, Mr. Louis J. Caruso, and students have used particle track etch and other techniques to study the location and distribution of uranium with respect to mineral grain boundaries, microcracks, and clay components. Recent results, based in part on improved resolution (on the order of microns), indicate that popular models and theories must be modified or discarded, e.g., uranium once ascribed to grain boundaries has been shown to be located in sealed microcracks, and mineral hosts for uranium have been misidentified. These findings bear on our understanding of the origin, deposition, and migration of uranium in the earth's crust and our plans for selecting and engineering repository sites for radioactive waste.

NRL's capability for supporting research that relies on the neutron activation technique of trace analysis has been significantly enhanced by the recent addition of Dr. Ilhan Olmez, an experienced radiochemist, to the Laboratory staff. He replaces Dr. Morteza Janghorbani, who last year resigned from his position at NRL to accept a faculty appointment at Boston University's School of Medicine. Dr. Olmez has been actively engaged in a number of environmental research projects that use neutron activation analysis, and he brings this expertise to NRL. He and Mr. William Fecych are modifying the technique as applied to analyses of fly ash in order to improve on the technical support for the coal combustion research of Professor Adel F. Sarofim in Chemical Engineering. Meanwhile Dr. Janghorbani and his radiochemistry group at Boston University are continuing their activities in the area of stable isotope applications in human studies and are using the MIT Reactor to activate samples and NRL counting equipment to analyze them. In earlier research they developed methodology for metabolic studies of MIT young adults in the areas of zinc, selenium, and copper nutrition. Much of the work is based on recently developed concepts of biologically labeled foods and has been carried out for the first time at MIT. In addition to their metabolic studies, carried out jointly with Professor Vernon R. Young of the Department of Nutrition and Food Science and the MIT Clinical Research Center, they have continued to develop collaborative programs in areas for which stable isotopic methods are the sole practical approach: studies with neonates, mineral metabolism in relation to human pregnancy, and many human metabolic disorders. They have ongoing programs with researchers at such other institutions as Wayne State University (zinc marginal decline in man and homeostasis of zinc-copper in Wilson's disease) and Yale University (mineral nutrition of neonates). Additional projects that are being developed include the use of lanthanides as non-absorbable markers, initiation of selenium metabolic studies in infants, and use of rubidium and bromine as markers in body composition study.

In collaboration with Professor Alexander Varshavsky and Dr. Robert M. Snapka, Biology Department, neutron radiography has been combined in a unique manner with chromatograph evaluation of amino acid systems. In initial studies assay sensitivity was increased by an order of magnitude. Work during the past year has resulted in further substantial gains in sensitivity.

**COMPUTER CONTROL OF REACTORS**

Professor David D. Lanning, Nuclear Engineering Department, and Dr. John A. Bernard continued studies on the closed-loop, digital control of nuclear reactors, providing both steady-state and transient operation. A general set of control principles, based on reactivity constraints and intended for non-linear situations, 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, which is supported by the National Science Foundation (NSF), resulted in six publications and three major accomplishments during the past year. The first accomplishment was that the US Nuclear Regulatory Commission approved an amendment to the MIT Reactor's license that permits the automatic control of the reactor's shim blades. (Previously, such permission existed only for the fine control regulating rod.) Closed-loop control experiments can now be performed without a priori restrictions on the associated reactivity. The issuance of this license culminated an 18-month effort in which safety evaluations were prepared. The significance of this amendment 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 closed-loop control. This gives the reactivity constraint concept an enormous lead over competing ideas in the United States. The project's second major accomplishment during the past year was the successful completion of closed-loop control experiments using actuators with differential worths that were a factor of five greater than those previously tested. The third accomplishment was the first use of 'fuzzy' logic in the closed-loop control of reactor power. This work may lead to controllers based on cognitive models of the human decision process.

A collaborative effort with the Charles Stark Draper Laboratory in the areas of signal validation and fault detection remains ongoing. This research resulted in two S.B. theses during the past year. Real-time demonstrations of this technology were conducted during the 1985 Annual Meeting of the American Nuclear Society.
NUCLEAR MEDICINE

Professor Gordon L. Brownell, Nuclear Engineering Department, continues a program of basic study leading towards the successful application of boron neutron capture therapy. Working with Dr. John Kirsch, track etch autoradiography has been developed to determine the boron distribution in tissue samples. Resolutions approaching the theoretical limit of about 0.5 μm have been achieved and make it possible to determine boron distributions at the cellular level. Under study is the feasibility of using electron microscopy and image processing, which could further improve resolution by orders of magnitude. We will participate in the Second International Symposium on Boron Neutron Capture Therapy to be held in Tokyo in October 1985.

Medical imaging using reactor produced isotopes is assuming increased importance in biomedical research. Studies of F-18 production at the MIT reactor have indicated that this isotope can be produced in adequate quantities. Subject 22.55 Biological and Medical Applications of Radiation and Radioisotopes (Professor Brownell) and Subject 22.56 Principles of Medical Imaging (Professors Brownell, Nelson and Lele) make use of the MITR-II. Twelve and fourteen students, respectively, were enrolled in these two subjects.

Enrollment in a new master's subspecialty in Radiation Health Physics, initiated in 1982-83 by Professor Otto K. Harling and Dr. Barry W. Wessels, expanded to seven students and promises further growth next year. This program in the Nuclear Engineering Department is designed to educate students to a high level of proficiency in radiation management and control. An important part of the curriculum involves use of the MITR-II, the Bates accelerator, and various other radiation-related facilities in the Boston area to provide realistic laboratory experience for the students. It is especially timely in view of the recent study for the US Department of Energy by Oak Ridge Associated Universities, "Personnel Requirements, Education, and Training for Civilian Nuclear Activities, 1984-2000" (ORAU-231), indicating that some shortages of health physicists now exist at all levels, but large shortages are likely to develop before 1990 and continue into the next decade.

REACtor IRRADIATIONS AND SERVICES FOR RESEARCH GROUPS OUTSIDE MIT

In nuclear medicine the development and production of radioisotopes for use by researchers at hospitals and other universities included: 1) production of Cl-38 for Drs. Bernard Hoop and D. C. Johnson, of the Pulmonary Unit in the Department of Medicine, Massachusetts General Hospital, who continue their studies on control of ventilation through the regulation of chloride ions in the cerebrospinal fluid in a dog model, 2) production of Au-198 seeds for cancer therapy for Dr. Philip Cobb of the New England Deaconess Hospital for use there and in other area hospitals; 3) research activities by Professor Webster S. S. Jeff'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, 4) production of Re-188 and Dy-165 for Dr. Michael R. Zalutsky of the Whitaker College of Health Sciences, Technology, and Management for research studies in the treatment of arthritis, 5) production of Cu-64 and Sr-85 for use by Massachusetts General Hospital for calibration of a new positron emission tomography (PET) scanner, 6) production of Au-197 Mössbauer sources for the Chemistry Department at Northeastern University to study the chemistry and structure of gold compounds, particularly those exhibiting anti-arthritis and anti-tumor activity; 7) activation of biological samples for trace analysis by Dr. Janghorban's group at the Boston University School of Medicine, as described earlier, and 8) use of the reactor by Cadema Medical Products, Inc., of Middletown, New York, to irradiate cerium for the production of cerium-141 for a feasibility study; nuclear medicine studies indicate that this isotope is desirable as a source implant for treatment of some specific tumors.

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) the irradiation of sulfur targets for the production of 12 Curies per week of P-32 to label proteins for use in biological research was continued; 2) a Wellesley College UROP student, supervised by Professor Gene M. Simons of the MIT Department of Earth, Atmospheric and Planetary Sciences, used solid state nuclear track detection techniques to study the distribution of uranium and thorium in New England granite; 3) further research in geology using neutron activation analysis (NAA) for trace element determination was carried out by Professor Ray A. Coish of Middlebury College and three of his students; 4) Professor J. Christopher Hepburn and Rudolph Hon and eight students of Boston College used NAA to determine trace elements in geological systems; 5) additional irradiations were conducted for neutron activation analysis of filter and oceanic sediment by Dr. A. Fleer and two research assistants at the Woods Hole Oceanographic Institute; 6) 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; 7) Professors G. Collins and C. Hohenemser, with one graduate student, Clark University, again irradiated targets to make Mössbauer sources for study of the nuclear relaxation of dysprosium-161 in gadolinium above the Curie point; 8) Professor John Vetelino and two Electrical Engineering students irradiated SiO2 and AlPO4 piezoelectric crystals to determine the effect of neutron irradiation on the electrical properties of these devices; 9) Harvard University Professor William Paul, Department of Physics, and a graduate student irradiated various silicon crystals to evaluate the neutron transmutation doping of silicon to phosphorous; and 10) Dr. Robert Var of the Charles Stark Draper Laboratory irradiated charge coupled devices in the fast
neutron flux facility; these irradiations were done to determine the "radiation hardness" of these devices in a 1 MeV equivalent neutron flux; 11) a Physics student from Bates College under the direction of Professor Gene Clough used the reactor medical room beam to demonstrate the technique for authentication of paintings using a series of autoradiographs; 12) Dr. Gerald Entine of RMD, Inc., Watertown, Massachusetts, using cadmium-telluride crystal photon detectors, measured the radioactive component of our reactor tank gaseous effluent; a special sampling system was installed and the results were compared with the data obtained by the reactor Radiation Protection Office; 13) samples of aluminum oxide were irradiated for Dr. Forrest C. Burns at the Army Materials and Mechanics Research Center, Watertown, Massachusetts, to determine, by neutron activation analysis, their titanium content.

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. One of the largest groups, 78 seniors from Gould Academy, Bethel, Maine, spent most of a day at the reactor plus other parts of MIT for an in-depth look at fission power, fusion, and nuclear medicine. 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, 40 students, 9 visits; 2) Northeastern University, Physics Department, Course PHY 1555, 6 students, 5 visits; 3) University of Massachusetts, Harbor Campus, Department of Physics, Physics 697, 10 students, 11 visits.

A new education 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 was initiated. Two classes (two four-hour days each) were held with very enthusiastic response. Plans are being made to expand the program to 15 classes for the coming year.

INTERNATIONAL SYMPOSIUM PROCEEDINGS

Last year we reported on the October 1983 International Symposium on the Use and Development of Low and Medium Flux Research Reactors, hosted by NRL and attended by 208 registrants from 21 countries. The proceedings were published during the summer of 1984 in book form, hard cover, 1100 pages, by Karl Thiemig Publishing Company as Supplement to Vol. L4 (1984) of the journal Atomkernenergie-Kerntechnik. The 146 papers in the volume cover research utilization of these reactors in numerous disciplines and in training, as well as descriptions of past reactor upgradings and plans for major improvements in the future.

MIT RESEARCH REACTOR

The MIT Reactor completed its 26th year of operation, its tenth 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 86.3 hours per week at full power, holidays included. Energy output for the MITR-II, as the upgraded reactor is now called, totaled 186,312 megawatt-hours at June 30, 1985. The MITR-I generated 250,445 MWh 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, was increasingly used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. The neutron beam ports saw substantial utilization for neutron diffraction experiments. The number of material specimen irradiations was 2700, close to last year's total. Theses and publications on research supported by the reactor are running at about 14 and 50 per year, respectively.

The US Department of Energy (DOE) renewed its reactor-sharing grant whereby MIT is reimbursed for use of the Reactor by other educational institutions needing such a facility for teaching or research purposes. Nearly 200 students and 51 faculty and staff from 14 educational institutions (including teaching hospitals) benefited from visits and use of the MITR. Continuation of this funding has been granted for the coming year. DOE is also supplier of fuel to university research and training reactors and has selected Babcock and Wilcox (B&W), Lynchburg, Virginia, to continue the fabrication of these fuels. B&W is now commencing production of another batch for the MITR-II.

Late in the year MIT received a first-time grant from DOE in support of operation of the MITR-II. In connection with the generic question of such support for university reactors, DOE has recently undertaken a study of whether the Federal Government provides adequate financial assistance for the operation of university research and training reactors and the research programs that reactors of the former type 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 is assisting DOE to accumulate detailed information regarding research reactor accomplishments.
PERSONNEL

Mr. Lincoln Clark, Jr., Associate Director of NRL and Director of Reactor Operation, has been appointed by the Institute of Nuclear Power Operations as a member of its Accrediting Board, the body charged with decisions regarding the acceptability of nuclear utility training programs for its power plant operation, maintenance and supervisory personnel.

OTTO K. HARLING
During Fiscal 1985, 123 new invention disclosures were received (107 from campus and 16 from Lincoln Laboratory); 98 patent applications were filed (representing an 80 percent filing rate) and 51 patents issued in the United States in MIT's name. Additionally, corresponding foreign applications were filed on 9 US cases in an average of 12 countries per case. Gross royalty income from patent and copyright licensing totalled $1,868,842 representing a 50 percent increase over our original projection for this fiscal year. The significant rise in royalty receipts is largely related to the efforts expended in the licensing of MIT's computer software. Also, new license/option agreements were executed with 12 companies. In addition, industry committed approximately $978,000 in the form of research funding which is directly attributable to the licensing program, as this research support is in conjunction with option/license agreements to inventions.

During this period, the search for an Assistant Director which began at the end of last fiscal year was completed. Also throughout this year, emphasis has been directed towards the automation of the office, especially the computerization of the patent database. The patent, copyright and licensing database is expected to be fully operational by the end of calendar 1985. Such automation will afford improved faculty liaison by increasing responsiveness of the office invention disclosure review process. Such modernization efforts should also favorably impact upon our marketing and licensing activities. In addition, an Ad Hoc Committee of outside experts from industry was formed to assist the Office in commercial evaluation of invention disclosures submitted.

ARTHUR A. SMITH, JR.
Plasma Fusion Center

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 Versatok 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) development of an innovative design for axisymmetric tandem mirrors with inboard thermal barriers, with initial operation of the TARA tandem mirror experiment beginning in 1984, 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 principally supported by the Department of Energy's Office of Fusion Energy. During the past year, the funding level has been approximately $26 million. There are approximately 330 personnel associated with PFC research activities. These include: 24 faculty and senior academic staff, 70 graduate students and 26 undergraduate students, with participating faculty and students from Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics; 95 research scientists and engineers and 16 visiting scientists; 60 technical support personnel; and 39 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 methods for heating and driving currents in plasmas at thermonuclear temperatures. The main Alcator experimental areas include: device operations (David Gwinn); confinement studies (Steve Wolfe); plasma-wall interactions (Earl Marmar); radio-frequency heating (Miklos Porkolab); data acquisition and computations (Martin Greenwald); and toroidal analysis (Dieter Sigmar).

During the past year, design has continued on a follow-up device to Alcator C, with the emphasis shifting from an all-superconducting experiment, called Alcator DCT, described in last year's report, to a more modest copper modification presently called Alcator C-MOD. These design efforts have been carried out by the toroidal systems development group (Bruce Montgomery and Ronald Parker). Alcator C-MOD, which could accomplish many of the same objectives as Alcator DCT in the area of long-pulse tokamak physics, would also provide useful supporting data for a high-field tokamak ignition experiment.

Ohio Confinement Studies: Confinement properties of pellet-fueled plasmas continue to be studied and are compared with those obtained using gas fueling. Careful measurement of electron and ion temperatures and detailed transport analysis supports the view that pellet fueling ameliorates an anomalous ion thermal conduction which is present in gas-fueled discharges. An ion thermal conductivity consistent with theoretical predictions based on collisional transport is often obtained in the pellet-fueled case. The cause of the anomalous ion conduction is unknown and remains under investigation.

In another area, the Alcator group has been gratified to find that ohmic-heating results from the new generation of large tokamaks (TFTR at Princeton, JET at Culham, UK) have fit closely the predictions made on the basis of size-scaling experiments performed on Alcator C in 1982. The Alcator C results, which are now referred to in the literature as "Neo-Alcator scaling," showed that the anomalous electron confinement time scaled as the cube of linear size of the device, rather than the square as had been previously assumed. The implication is that the large tokamaks have better confinement than had been predicted on the basis of empirical scaling laws used at the time of their design. Indeed, the maximum confinement time measured on JET is nearly one second, which is about two orders of magnitude larger than confinement times characteristic of tokamaks which operated in the mid-1970's.

Diagnostic Development: In the past year, a number of new and interesting results have come from the high resolution soft X-ray diagnostic program. Using a compact, high-resolving-power crystal spectrometer, radial profiles of line emission in the wavelength range 2.9 to 5.0 ÂÅ have been obtained. In one
set of experiments, the absolute wavelengths of the hydrogen-like $\text{Ar}^{17+}$ Lyman-$\alpha$ doublet have been measured with a precision of about 10 parts per million. In this way, the Lamb shift of the $1s$ level has been measured with a precision of about 4%, and the results are in excellent agreement with the predictions of quantum electrodynamics.

In a second set of experiments, charge transfer between $\text{Ar}^{17+}$ and intrinsic neutral hydrogen has been identified, and the measurements have been used to obtain the neutral density profile. This is the first time this quantity has been measured. In addition, transfer from $n_0$ in its first few excited states, to $\text{Ar}^{17+}$, has been identified experimentally for the first time. This latter process populates very high principal quantum number Rydberg levels in $\text{Ar}^{16+}$ (up to about $n=40$) and cross sections for these reactions have been estimated.

RF Heating and Current Drive: During 1984-85, considerable progress was made in the Alcator C rf heating program. To review, during 1983-84, using two sixteen waveguide arrays ("grills"), efficient plasma heating was demonstrated in the density range $10^{14}$ cm$^{-3}$ $< n_e < 2 \times 10^{14}$ cm$^{-3}$ when standing waves were set up in front of the waveguide mouths ($\Delta T_e \sim \Delta T_i \sim 1$ keV at $P_{rf} \leq 850$ kW, $n_i \sim 1.5 \times 10^{14}$ cm$^{-3}$ was achieved). Furthermore, efficient plasma current generation was demonstrated at densities $10^{13}$ cm$^{-3}$ $< n_e < 10^{14}$ cm$^{-3}$ when traveling waves were launched by the waveguide arrays ($I_p < 220$ kA). These are the highest densities achieved in any tokamak in the world where either auxiliary heating, or rf current drive was employed.

During the past year, a third sixteen-waveguide array was added to the system, for a total of 48 waveguides appropriately phased to launch either a traveling wave (for current drive) or a standing wave (heating). The source rf power capability was increased to 3 MW, and a total net power of 1.5 MW was injected into the tokamak. Subsequently, several impressive physics experiments were carried out with the aid of new diagnostics, with the following significant results: energy confinement times were measured during both rf-driven plasmas, and rf-heated plasmas, in the density range $2 \times 10^{13}$ cm$^{-3}$ $< n_e < 1.5 \times 10^{14}$ cm$^{-3}$. Similar to neutral-beam-heated plasmas, deterioration of the energy confinement time was observed relative to ohmically heated plasmas as the density and rf power were increased above ohmic levels. These studies were carried out in the unique regime $0 < P_{rf}/P_{OH} < 1$ (the infinite value is obtained in rf-driven plasmas). The data obtained in these experiments are being analyzed at present.

In another set of experiments, as the rf power was raised, plasma current ramping was demonstrated at densities $10^{13}$ cm$^{-3}$ $< n_e < 3 \times 10^{13}$ cm$^{-3}$. Up to 10% of the rf energy could be transformed into the poloidal field energy of the tokamak. These densities are nearly an order-of-magnitude higher than those used in similar experiments at Princeton University. An additional benefit of these techniques is the demonstration of the feasibility of "recharging" the ohmic heating transformer while the plasma current is maintained by the rf source.

Another exciting result obtained very recently was a demonstration of the stabilization of "saw-tooth oscillations" near the plasma center when traveling lower-hybrid waves were launched to generate off-axis rf-driven toroidal current (in addition to ohmic currents). This effect was demonstrated at a density of $n_i = 1.1 \times 10^{14}$ cm$^{-3}$ and magnetic field $B = 6.1$ tesla, a regime relevant to tokamak reactor parameters.

During 1984-85, two types of ion cyclotron wave launching antennae were designed and constructed. One of these antennae will be used to launch the so-called Bernstein type of ion cyclotron wave. These waves are short wavelength electrostatic waves which may be absorbed by either a minority ion species, or by nonlinear mechanisms, leading to bulk ion plasma heating. Initial experiments in Japan and Princeton have shown promising heating results at densities $n_e < 4 \times 10^{13}$ cm$^{-3}$. This technique will be tested to heat plasmas at densities $n_e > 10^{14}$ cm$^{-3}$. An improved fast-wave launching antenna is also being fabricated. This antenna will be used to launch the fast magnetosonic wave which may be absorbed by either a minority ion species near its cyclotron resonance, or at the harmonic of the majority ion species. The technique which works best will be used to heat plasmas in the proposed Alcator C-MOD device.

Alcator C-MOD: A Proposed Modification to the Alcator C Facility: The success of Alcator C in achieving a Lawson parameter in excess of that required for breakeven at higher temperatures has underscored the value of the high-field, high-density tokamak. Present plans for a near-term ignition experiment focus on this approach as the most promising and economical means of exploring fundamental issues associated with the physics of burning plasmas. The Alcator C-MOD facility is proposed as an upgrade to Alcator C aimed at investigating the characteristics of high-temperature, ICRF-heated plasmas, with the goal of understanding the physics of rf heating, confinement, stability, impurity control, fueling, and shaping of high-performance tokamaks. The information obtained on Alcator C-MOD will be a significant benefit to the design and implementation of a high-field ignition device.
Concept improvement is a second major emphasis in the national fusion program. The Alcator C-MOD facility will enhance the ability of the MIT fusion program to address issues related to the ultimate goal of an attractive steady-state tokamak reactor. By operating at reduced fields, Alcator C-MOD can operate for 10-second pulses, and the combination of improved rf access and an expanded boundary divertor method of impurity control provide key elements in seeking more efficient methods of noninductive current drive. In this way, Alcator C-MOD will be able to carry out many of the physics programs planned for the more ambitious Alcator DCT device.

Alcator C-MOD will feature a major radius of about 75 cm, slightly larger than Alcator C, with an aspect ratio of 3 and elongation up to 1.8. The toroidal field capability will be 10 tesla, less than the design field of Alcator C but permitting plasma currents up to 4 MA (compared to 0.8 MA in Alcator C) and density above $5 \times 10^{14}$ cm$^{-3}$. The principal qualitative improvements over Alcator C, besides the elongated, D-shaped cross section, include greatly increased access for rf heating, power removal, and diagnostics, and an expanded boundary-divertor configuration for impurity control and possible confinement enhancement (H-mode). The design provides for approximately 10 MW of rf heating in the ion cyclotron frequency range.

MIRROR CONFINEMENT EXPERIMENTS

The Mirror Confinement Experiments Division, headed by Richard S. Post, is involved in the design, construction, and operation of a medium-scale tandem mirror research facility called TARA. The completion of the experimental facility and the initiation of experiments, TARA represents a major step forward within the national fusion program. The primary objective of TARA operation during the past year was to use high-power rf waves to explore the basic stability and transport properties and to increase the understanding of the important physics issues inherent in high-power rf heating. In the longer term, experimental studies will include microstability properties, thermal barrier formation, and alternative potential enhancement schemes. The main areas of activity include: TARA operations (Marcel Gaudreau); experimental systems (Don Smith); and computations and advanced concepts (Jay Kesner).

TARA Tandem Mirror Experiment: The TARA device is currently in its second 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 completes the major part of TARA construction, new diagnostic and heating and fueling systems were added to the central cell and axisymmetric plug. Preliminary experiments with the new TARA configuration indicate improved plasma performance in the central cell, and plug parameters appropriate for successful neutral beam injection experiments, which are scheduled to begin in August, 1985.

The TARA tandem mirror consists of a 10 m solenoidal cell bounded by axisymmetric confining plugs and an outboard minimum magnetic field MHD anchor. The configuration was designed to minimize radial particle transport arising from the net radial drifts of ions bouncing in a nonazimuthally symmetric field. Among the major physics objectives of TARA are to investigate (1) plasma stability, (2) central cell radial transport, and (3) the formation of enhanced potential barriers in the plugs to control ion and electron axial transport.

Past experiments on TARA have focused on optimization of the central cell and anchor parameters. Based on data obtained during 1984, the central cell heating and fueling systems were redesigned to reduce hot ion loss 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 neutral beam buildup of the plasma. With the new configuration, gas was injected at the ends of the central cell. Now, however, it is injected at the central cell midplane into a region where the magnetic field is approximately twice that in the remainder of the central cell. Hot ions are trapped in the two mirror regions on each side of the midplane and do not pass into the region of high neutral pressure, where they could be lost by charge exchange. In principle, the energy confinement time should approach the ion-ion pitch angle scattering time. Although this has not yet been demonstrated experimentally, greatly improved gas use has been achieved with the new fueling system. Most importantly, the neutral gas pressure in the plug is now sufficiently low for neutral beam operation.

A second double-half-turn ICRF antenna was added to the central cell, bringing the number of central-cell ICRF antennae to three. Both the double-half-turn antennae and the aperture antenna (located near the midplane) heat the plasma most efficiently when the fundamental cyclotron resonant frequency is located near the magnetic field minimum. Second harmonic resonant heating is planned for August, 1985.

While the TARA plasma parameters in the central cell are continually being improved, some results obtained thus far have already surpassed those of last year. With 700 kW of ICRF power the ion temperature is on the order of 300 eV, the density is from 2 to $3 \times 10^{12}$ cm$^{-3}$, beta is about 0.5%, and the energy confinement time is about 0.5 ms as measured from the decay of diamagnetism at rf turnoff. In addition, plasma fluctuations, which degrade confinement, are at generally lower levels than last year. Several new electric and current probes have been added to the central cell in order to study the azimuthal structure of the fluctuations, from which stability limits in TARA may be determined.
Two 18 GHz klystrons are to be installed in the anchors, increasing the ECH power and allowing hot electron beta values greater than 15% to be obtained. One of the main issues to be resolved before proceeding with full-scale neutral beam operation is the stabilizing influence of hot electron beta and hot ion beta (produced by ICHP) in the anchor on the central cell and plug plasma curvature-driven modes. The two neutral beam sets, which consist of three sources per set, have been operated successfully on a test stand. One of these sets is scheduled to inject into TARA in August, 1985, and the other during the fall. A primary goal is to produce the so-called "sloshing ion" distribution necessary for electrostatic potential barrier formation. Two 28 GHz, 200 kW gyrotrons purchased from Varian Associates, Inc. will provide electron cyclotron heating in the plug in order to enhance the ion-confining potential and to create a thermal barrier to isolate the potential barrier from the deleterious effects of cold central cell electrons.

It is anticipated that all of the TARA heating systems will be operational by the fall of 1985, with thermal barrier studies to begin in 1986.

Computations and Advanced Concepts: The TARA research program has a combined theoretical and experimental effort which permits a close collaboration between experiment, theory, computation, and reactor design. Areas of emphasis include low-frequency stability (trapped-particle and MHD theory), microstability, and rf heating theory, as well as the development of promising new magnetic geometries.

In order to gain a better understanding of results from the axicell gyrotron heating experiments, the theory of hot electron interchange modes has been pursued. The experiments indicate that plasma dumps occur at high azimuthal mode numbers, typically 5 to 10. The effect of line tying on this instability has been considered. For hot electron modes, line tying can be particularly important because the high drift frequency of the hot electrons can cause them to decouple from the core when, due to line tying, the growth rate is reduced. Additionally, the reduction in growth rate is enhanced because the high wave frequency will tend to exceed the electron collision frequency, which tends to reduce sheath resistivity effects. The net qualitative result of these effects is to stabilize low azimuthal mode numbers.

The electrostatic coupling between mirror cells (specifically the axicell and the anchor), which produces hot-electron trapped particle modes is also being explored. This coupling should also preferentially stabilize low mode numbers. However, this effect cannot explain the observations, since the instability frequency (and presumably mode number) appears to be independent of anchor heating.

In collaboration with the Institute for Fusion Studies (University of Texas, Austin), the formalism for a variational quadratic form has been developed suitable for the analysis of low-frequency, fully electromagnetic perturbations. Several applications have been considered using this formalism. It has been shown, using the MHD equations, that at sufficiently high beta, a mirror configuration can be stabilized by the presence of a conducting wall. This analysis was extended by showing that the condition $\beta = 0$ gives the lowest energy perturbation, and therefore that an electrostatic mode will be stable if the MHD mode is stable. The radial and axial problem of two coupled cells with differential azimuthal rotation was also analyzed assuming first a low-beta sharp-pressure profile, as was the interaction of MHD and electrostatic ballooning modes in the presence of a strongly stabilizing anchor in the eikonal limit.

A scoping study is being performed of a wall-stabilized tandem mirror reactor. Wall stabilization offers the possibility of a particularly simple, axisymmetric system, similar to the central cell - axicell region of TARA. The central cell would run at high beta which results in designs with low central cell fields, low recirculating power, high neutron wall loading, and a short, compact central cell. Axicell wall stabilization has been shown to be compatible with thermal barrier formation, and the short thermal barrier length of the axicell results in reduced requirements on central cell length for ignition.

A novel tandem mirror stabilization scheme is being developed which introduces a magnetic limiter at the central cell midplane. The resulting ring null is located on a local magnetic maximum and thus connects to a flux tube which can adiabatically confine ions that do not enter the null where they would be non-adiabatically scattered. Null-passing electrons do scatter both in pitch angle and in azimuth. This geometry has been found to stabilize MHD and trapped-particle modes with azimuthal mode number equal to unity. This stabilization requires finite pressure out to the flux surface containing the null. Locating the limiter null in a baffled magnetic hill region will further reduce gas influx into the region where confinement of hot ions is desired.

**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 (George Bekefi, Miklos Porkolab and Stan Luckhardt); experimental
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. Significant progress has been made in the past year in several experiments which have taken advantage of the newly upgraded capability of Versator II including the ability to study fully rf-driven plasmas without ohmic heating.

A universal feature of lower-hybrid current drive experiments to date has been a "density limit." Efficient lower-hybrid current drive appears to be possible only when $\omega/\omega_{LH} > 2$ where $\omega_{LH}$ is the lower-hybrid resonance frequency. Above a critical density, the current drive efficiency suddenly drops and current drive effects disappear. In previous 800 MHz experiments on Versator II this limit occurred at a density of $n_e = 6 \times 10^{12} \text{ cm}^{-3}$. In the present experiments, a new 100 kW rf system operating at 2.45 GHz is being used to study the frequency dependence of the density limit. Versator II thus has the unique capability of direct comparison of current drive at two frequencies, 800 MHz and 2.45 GHz, on the same tokamak under the same conditions. With the new system, fully rf-driven plasmas have been achieved at densities as high as $n_e = 1 \times 10^{13} \text{ cm}^{-3}$, substantially exceeding the 800 MHz density limit, and current drive effects are observed up to $n_e = 2.5 \times 10^{13} \text{ cm}^{-3}$. The possibility that nonlinear parametric decay instabilities prevent the wave power from reaching the center of the plasma above the density limit is being investigated.

The propagation and absorption of lower-hybrid waves in toroidal plasmas have been the subjects of several experiments on Versator II. A microwave scattering diagnostic was used to detect directly the externally launched 800 MHz lower-hybrid waves in the current drive regime. Experiments to date have concentrated on measurement of the $k_L$ spectrum of the lower-hybrid waves as a function of position in the plasma. These data will be compared with the theoretical predictions of ray propagation in a toroidal plasma.

In previous experiments on Versator II, a regime of operation was found that combined inductive-ohmic with lower-hybrid current drive to improve particle confinement time, $T_P$, by a factor of 2 above the case without rf power. This improved confinement behavior was then found to be correlated with stabilization of the anomalous doppler relaxation mode. Ongoing experiments are investigating possible changes in the energy confinement time, $\tau_E$, in the improved confinement regime, and in fully rf-driven plasmas. The necessary electron temperature measurements are made with a ruby laser Thomson scattering apparatus capable of temperature measurements at seven radial locations. Further experiments attempting to identify the physical mechanism responsible for the improved confinement behavior are under way using magnetic probes. So far, initial probe experiments have identified anomalous increases in magnetic fluctuations correlated with the presence of the anomalous doppler instability.

In 1985, construction of a new electron-cyclotron resonance heating (ECRH) system began. The ECRH experiment, which is a collaborative effort with the Naval Research Laboratory (NRL), employs a gyrotron power source currently under construction at NRL. The gyrotron will operate at a frequency of 35 GHz at a power level of 150 kW. The transmission system and antenna are being designed at MIT. These experiments will test heating and current-drive processes using combined rf power near the lower-hybrid frequency and the electron-cyclotron frequency.

A new current-drive experiment is also under construction which will employ 800 MHz fast lower-hybrid waves. Current drive experiments to date have used slow lower-hybrid waves, but in plasmas approaching fusion reactor conditions, the slow-wave current drive efficiency is predicted to be relatively low in comparison to that of the fast wave. To launch the fast wave in Versator II, a dielectrically loaded, phased-waveguide-array structure has been designed and is being fabricated by industry. This experiment is expected to become operational in 1986.

Constance B: Constance B is a quadrupole mirror device of moderate size in which high-beta (beta is the ratio of plasma pressure to magnetic field pressure) 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 and stability properties of mirror-confined hot electron plasmas. Investigations of radial potential control and radial ion pumping in hot electron plasmas are a fundamental part of the Constance B research program. The design of a second mirror machine, Constance AP (Advanced Plug), has been under way since January, 1985. This device will be used to study plasma generation and stability in an octupole magnetic mirror.
During the past year, the Constance B experiment was operational for three months. Two failures of the surplus LLNL quadrupole magnet due to internal shorting caused the loss of run time. The second failure was not repairable and a new coil was fabricated. Experiments were resumed in June, 1985.

Understanding hot electron microstability and power balance is essential for the development of the thermal barrier, a means to increase the plasma confinement in tandem mirrors. The hot electron microinstability observed in Constance B is now believed to be the whistler instability. Dispersion relation calculations predict frequency regimes for the whistler instability which are in close agreement with the experimentally observed emission frequencies. In addition, the growth rates for the whistler instability are an order-of-magnitude larger than those of the cyclotron maser instability for the parameter regimes of interest. Studies of the instability as a function of ECRH power and neutral pressure are in progress. Hot electron power balance and ECRH heating studies continue. Comparison of the observed hot electron heating rates with simple heating models and Fokker-Planck calculations is underway.

All hardware design for the radial potential control experiments has been completed. Potential control is required for reduction of transport in tandem mirrors. Fabrication and testing of the diagnostics are nearing completion and construction of the recircularization coils will begin in July. These experiments will be carried out in the fall of 1985.

In the area of radial ion pumping, the ICRH and drift pumping systems have been completed and will be installed in the machine in late July, 1985. Drift pumping is a means by which selected low energy ions trapped in a thermal barrier can be caused to drift across the magnetic flux surface. Removal of these low energy ions is required to generate ion confining potential efficiently for the reactor parameter range. A drift pump field of 100 gauss at the antenna has been measured, which will be sufficient to see drift pumping, according to theory. These will be the first drift pumping experiments performed in the mirror program.

Interest in octupole end plugs for tandem mirrors has motivated the design of the Constance AP experiment. Octupole end plugs offer the prospect of reduced radial transport and lower cost relative to quadrupole end cells. The basic physics of the octupole mirror plasma is sufficiently complex that it is desirable to study the issues in a single cell experiment before constructing octupole end cells on the TMX-U experiment at LLNL. The issues of hot electron pressure profile generation using ECRH and MHD stability will be addressed in Constance AP. The machine will be constructed using some of the coils and vacuum chambers of the earlier Constance II device. The octupole magnet and vacuum chamber design will be completed in August, 1985, and fabrication will begin later this year.

In the plasma theory and computations area recent studies have included: (a) stability of mirror-confined plasmas to low-frequency modes including trapped-particle effects, as well as the development of concepts related to novel magnetic field geometries; and studies of the equilibria of tandem mirror plasmas in the "long-thin" approximation, (b) for tokamak plasmas, studies of ignition physics and transport and heating processes in fusion plasmas, e.g., the internal kink instability when the ion gyroradius is comparable to the resonant layer width; microscopic reversibility in the theory of cross-field transport fluxes; effect of the ambipolar electric field on impurity transport; energy confinement scaling in tokamaks with strong auxiliary heating; ballooning-mode stability including finite Shafranov shift; and fundamental physics constraints of fusion reactor design, (c) in the rf-heating and current drive area, calculations of the efficiency of lower-hybrid current drive and comparison to Alcator C, showing promise for fast lower-hybrid-wave current drive; analysis and computations of new means for creating confining potentials in tandem mirrors using frequency-modulated electric fields near the electron-bounce frequency in the mirror field; and development of a variational principle for the lower-hybrid-driven plasma current including strong rf diffusion, (d) in the area of fundamental turbulence theory, numerical simulation of the growth of phase-space holes and development of intermittent plasma turbulence; and application of strong turbulence theory to MHD-wave and drift-wave spectra, (e) fundamental nonlinear studies of the influence of stochastic magnetic fields on the turbulent transport and heating of fusion plasmas, and (f) continued theoretical investigations of free electron lasers, including the development of advanced concepts, studies of harmonic generation, and the development of nonlinear models for mode saturation and efficiency enhancement.

In the area of plasma diagnostics development, a 140 GHz gyrotron is being fabricated with output power levels of 1 to 10 kW in 30 ms pulses and with narrow linewidth (< 1 MHz) for collective Thomson scattering diagnostics on the TARA tandem mirror experiment. The main goal of this diagnostic will be to study scattering from instability-driven ion density fluctuations in the TARA end plugs. The instabilities of interest are the drift cyclotron loss cone (DCLC), the axial loss cone (ALC), harmonics of the DCLC and ALC, and the ion two-stream instability. Moreover, scattering from electron plasma waves will be attempted to determine whether this diagnostic technique can be used to locate the position of the potential dip in the thermal barrier region of a tandem mirror. Density fluctuation levels will be measured as a function of wave vector, position, and time. This scattering diagnostic will have the capability of detecting thermal-level fluctuations in order to investigate the role of fluctuations in the growth of microinstabilities. Recently, a 137 GHz gyrotron with a high Q (~6000) cavity has been built and tested.
Output power of 0.1 to 20 kW and efficiency of up to 26% were observed in operation in the TE_031 mode. Future goals will be to demonstrate high-power gyrotron operation at frequencies above 600 GHz for diagnostic applications in tokamaks.

Coherent Free Electron Radiation Sources: Experiments, theory, and computer simulations of millimeter and submillimeter free electron lasers are continuing. Experiments have demonstrated the predicted frequency tuning with electron energy, electron beam current, and wiggler strength. The results represent a first detailed comparison of experiments with recent three-dimensional free electron laser theory.

Good electron beam quality is a prerequisite for efficient free electron laser operation. Field-emission studies using various cathode materials have resulted in a novel, low emittance, high brightness, electrostatically focused electron gun.

The design of a tunable 1-10 micron wavelength, free electron laser is in progress. The facility would include a novel wiggler comprised of a standing electromagnetic wave trapped in a resonant cavity, and energized by high-power millimeter wavelength gyrotrons. In addition, a more conventional tapered, permanent magnet wiggler would be used.

FUSION TECHNOLOGY AND ENGINEERING

The Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides critical engineering analysis for the advanced design projects, and develops advanced superconducting and high-field copper magnet technology for the national fusion program. Research activities include: engineering support for the Alcator DCT advanced design and the modification of Alcator C, designated as Alcator C-MOD, (Bruce Montgomery); advanced magnet design in support of the Tokamak Fusion Core Experiment (TFCE), Ignition Studies Program (ISP) and Ignitor devices, and the INTOR International Tokamak Reactor study (Richard Thome and Joel Schultz); concept development for improved magnetic divertors for tokamaks and mirror upgrades and next-generation test reactors (Ted Yang); development of forced-flow superconductors for application to advanced fusion devices (Mitchell Hoenig); basic research on the development of ductile superconducting materials (Simon Foner); advanced magnet design in support of DOE programs in MHD and high energy physics (Peter Marston and John Tarrh). Recent research activities in these technology and engineering areas are summarized below.

In 1984, a significant national effort was underway in the preconceptual design of a long-pulse ignition experiment called the Tokamak Fusion Core Experiment (TFCE). This effort, led by the Princeton Plasma Physics Laboratory (PPPL), was discontinued in late 1984. The Plasma Fusion Center provided major technical support to that activity, with responsibility for both poloidal field magnetic system design and analysis and cryogenic system design and analysis. Due to changes in the scope and direction of the national fusion program, the TFCE design activity was discontinued at the end of 1984 and a new study program, the Ignition Studies Program (ISP), was initiated. ISP has two principal missions: Mission I explores compact, high-field, copper ignition devices of which three have been chosen for further design and analysis; Mission II considers superconducting, long-pulse devices which are smaller and more efficient than TFCE. The three copper ignition devices - Ignitor, LITE (designed by MIT) and the PPPL ISP device - are now undergoing detailed study.

The MIT Plasma Fusion Center continues to play a major role in the advanced design of these devices, including code development for transient electromagnetics issues and concept evaluation for the Ignition Studies Program (ISP). The FCC finite-element codes have been modified to allow analysis of the pulsed operation of the toroidal field (TF) coil system. This has allowed better predictions of the peak power and energy requirements during the cycle because of a realistic modeling of the current-field diffusion into the conductor and the resistivity change with temperature. The effect of nuclear heating on the conductor can also be evaluated. Results have had a significant impact on the estimates for power and energy requirements for ISP at PPPL and on some of the fundamental design concepts for the TF coils in Ignitor. In addition, a technique for evaluation of alternate poloidal field (PF) coil locations has been developed for these systems codes to allow trade studies to be performed more rapidly. In addition, design and analysis of the PF coils and the cryogenic system have been conducted.

In conjunction with MDSA Corporation, a survey of all major U.S. magnet technology centers was made to gather and classify information on magnet system failures. A survey format was formulated; eighteen sources provided information on 31 events outlining where each failure occurred, what initiated each failure and how it was manifested. No event resulted in loss of life or in personnel injury, but 19 of the 31 failures caused significant project delays. These data will be applied to ISP Mission I designs to minimize the likelihood of magnet failure.
The Plasma Fusion Center has also played a significant role in the analysis of critical magnet design issues for the INTOR International Tokamak Reactor project. The PFC has the responsibility for the transient electromagnetics effort for the U.S. delegation to the INTOR Workshop. This involves direct interaction with contributors from the other major laboratories in the U.S. and with delegations from the European Community, Japan and the USSR. Transient electromagnetic effects impact the vacuum vessel and torus design requirements for start-up, plasma stabilization, and the ability of the torus to withstand the forces and voltages which result from a plasma disruption. Activity has focused on the requirements for vertical stability of the elongated INTOR plasma to provide preliminary design guidelines from the electromagnetic viewpoint for the next step in the evolution of a first wall, blanket and shield concept.

The Plasma Fusion Center also has a continuing program with Idaho National Engineering Laboratory (INEL) oriented toward large magnet safety and protection. The program involves collection and analysis of information on actual magnet failures, analyses of general problems in safety and protection, and performance of small-scale experiments. During the past year, studies were conducted into the parameters governing the conversion of magnetic to kinetic energy in the event of a magnet structural failure, and into the relative advantages of a multiple-circuit discharge system for toroidal field coil protection. In addition, investigations of a major magnet failure at the Arnold Engineering Development Center were completed; a preliminary study of the load conditions which could arise under selected faults in the TF or PF magnet systems for the TF coil at PPPL was performed; the catastrophic failure of a laboratory-scale dewar at the FBNML was analyzed; and small-scale tests were conducted on the pressure rise and burnout of an ICCS.

The Plasma Fusion Center has been active in developing improved magnetic divertor concepts. A long-burning fusion reactor must deal with the buildup and removal of helium "ash" and impurities, and magnetic or mechanical divertors are considered to be an extremely demanding but necessary component. Conceptual designs for reactor-scale bundle divertors are being investigated, and powerful numerical methods have been developed to study the recycle and exhaust for various divertor concepts. This group has provided strong technical support in designing the TARA transition region and the poloidal field and divertor systems for Alcator C-MOD, LITE, Ignitor and ISP.

Three principal tasks involving the use of internally-cooled, cabled superconductor (ICCS) include: (1) completion and test of the MIT 12 T test coil; (2) design of superconducting poloidal field coils for Mission II and Alcator DDT; and (3) design of the Multi-Purpose Coil (MPC) outer shell.

The successful testing of the 12 T test coil completes a 5 year program. It was the first test of a practical size [486 strand] ICCS, intended for use in magnetic fusion experiments. The MIT coil carried 15 kA of current at 11 T for 15 minutes with no sign of instability. A half-turn length in a 10 T field was able to absorb a heat load of more than 200 mJ/cm$^3$ of wire volume in 4 ms, while carrying a current of 12 kA. The critical current of the ICCS was mapped at fields up to 12 T for temperatures of 4.2 to 7.5 K and electrical sensitivities of 0.015 to 0.11 μV/cm. The critical current of the ICCS at 11.7 T was measured at 16.9 kA.

The MPC is to be a 1.8 m OD, 1.5 to 2 m tall solenoid, with a 0.3 m build, designed to: (1) provide a 10 T background field for high field mirror choke magnets at the Lawrence Livermore National Laboratory (LLNL), and (2) model a poloidal field (ohmic heating) field coil (with transients of the order of 100 T) in a future intermediate-size steady-state tokamak.

Technology development to date has demonstrated a conductor capable of a critical current of 24 kA at 10 T. The MPC conductor critical current requirement is approximately 30 kA which can be reached by replacing the ICCS (Fe, Cr, Ni) superalloy sheath with a low thermal expansion alloy sheath (such as an Fe-Ni Incoloy), which does not cause a reduction in critical current density due to thermal strain. Both subsize (27 strand) and full-size ICCS tests have been initiated to select commercial superconductors, fabrication techniques, and sheathing materials. A hard Cr wire coating method has been developed resulting in a sinter-free conductor activation procedure. Tests have shown that Cr-plated and plain wire cables have a low AC loss profile, when subjected to high inductive heating. A highly sensitive test has been developed for the measurement of joint resistance in ICCS cables. A full size ICCS conductor using an Incoloy 903 sheath has been wound into a test coil, which has been reacted and is being prepared for testing at the 9 to 10 T High Field Test Facility (HFTF) at LLNL. A second large test coil, consisting of a 150 m length of a 27 strand ICCS has been wound, insulated (using high temperature ceramic insulation) and reacted to be used for quench propagation and quench pressure measurements at the Karlsruhe Kernforschungszentrum (KfK) in Karlsruhe, West Germany.

Basic research on advanced superconducting materials is also a major fusion engineering activity performed in conjunction with the Francis Bitter National Magnet Laboratory. The objective is to develop materials and techniques for producing superconductors capable of generating 15 tesla magnetic fields. The powder metallurgy and the in situ processes are alternative technologies for producing fine fiber, multifilamentary, A15 superconductors with high overall critical current densities, $J_c$, at high fields and with good strain tolerance. It is clear that the performance of Nb$_3$Sn can be improved within rather
well defined limits to above $J_c = 3 \times 10^4$ A/cm$^2$ at 14 T, whereas the $J_c$ of Nb$_3$Al, which has reached of greater than $6 \times 10^4$ A/cm$^2$ at 15 T and 4.2 K and $>10^4$ A/cm$^2$ at 20 T and 2.5 K is expected to sh.

Advanced magnet development and design for the national MHD program and for selected high energy physics projects are also carried out. The principal MHD effort is to develop and test an internally cooled, cable superconductor (ICCS) suitable for the retrofit-scale superconducting magnet envisaged by the national MHD program. The ICCS configuration has been identified in previous studies as having the potential for substantial cost and risk reductions, while potentially enhancing reliability, particularly for systems requiring considerable field assembly. In the area of high energy physics, an advisory role is being played in the selection of the final magnet design for the superconducting supercollider. The group also contributes to the design of magnet systems for a number of medical applications including a device for trapping magnetite-bearing, drug-laden microspheres, and analytical backup for magnetic resonance imaging (MRI) magnet system design.

FUSION SYSTEMS

The Fusion Systems Division, headed by Daniel Cohn, investigates several aspects of fusion reactor design and develops advanced millimeter and submillimeter wave technology for plasma heating and diagnostics. Research activities include: safety and environmental studies (Mujid Kazimi); reactor system studies (Leslie Bromberg and Dan Cohn), blanket and first wall structural design studies (John Meyer); gyrotron and advanced millimeter source development (Richard Temkin); millimeter and submillimeter detector development (Peter Tannenwald, Lincoln Laboratory). Selected technical advances are summarized below.

Safety and Environmental Studies: Modifications of the LITFIRE code have been made to increase its utility in modeling fires in fusion reactor containments. The ability to monitor lithium-lead alloy reactions in air has been incorporated into the LITFIRE code. Also, the geometry has been made more flexible and the available options made compatible. Comparisons indicate that lithium-lead alloys are much less reactive than pure lithium. Work on a new code has been initiated.

Rapid numerical techniques have been developed for computing the 1-D structural response to eddy current loading in a torus such as may occur after a plasma disruption. Since the currents are directed toroidally, the structure and the driving currents are modeled as a set of circular loops which couple through mutual inductances. The resulting circuit equations are solved, and the structural response depends on the characteristics of the driving current.

Small-scale experiments have been conducted to measure the strain due to simulated plasma disruptions. The results indicate that the induced strains are about an order-of-magnitude higher in the regions of structural discontinuities.

Ignition Test Reactor Studies: Resistive-coil experimental devices offer the opportunity to explore the physics and engineering aspects of ignited plasmas at moderate cost. The design of a Long-Pulse Ignition Test Experiment (LITE) device has been developed in order to minimize cost and technical risk. The main objective of LITE is to demonstrate ignition (where the heating of the plasma is provided entirely by the fusion reaction products). Pulse lengths of $\sim 5$ s are required to study the physics of alpha-particle heated plasmas. Longer pulses would be possible with reduced fields. One design alternative for LITE includes the option of very long pulses ($\sim 30$ s) with steady-state water-cooled magnets and first wall. The size is smaller than that of the TFTR tokamak at the Princeton Plasma Physics Laboratory, operation at stress levels similar to those in Alcator C minimize the machine size and the associated power supply equipment, thereby reducing the cost of the experimental facility. The key feasibility issues for LITE-type machines have been studied. The magnets could be either steady-state or inertially cooled (starting at liquid nitrogen temperature). The toroidal field magnet is made of high performance copper-alloy plates.

Together with TRW, concepts for first wall and vacuum vessel have been developed for LITE-type reactors. The water-cooled vacuum vessel is capable of surviving full plasma disruptions. The first wall is made of graphite tiles that are mechanically attached to the vacuum vessel. Concepts for long-pulse operation with steady-state water-cooled panels with brazed tiles are being developed. After operation with tritium, it will be necessary to use remote maintenance for the device. For LITE, the minimum level of remote maintenance required is related to replacing the tiles and/or panels that make up the first wall.

Commercial Reactor Studies: In the past, tokamak reactor designs with normal resistive coils have received considerably less emphasis than designs with superconducting coils. The main disadvantage of resistive coils is the power consumption, which in a reactor would increase the recirculating power.
fraction. However, resistive coils have some significant advantages over superconducting coils. In particular, resistive magnets require less neutron shielding and offer the possibility of easy demounting. This allows for simple replacement of the first wall and for the positioning of poloidal field coils in the bore of the toroidal field magnet. High-beta reactors could be possible using in-bore poloidal field coils. The reactor designs would be smaller than superconducting reactors with the same output power, and the toroidal field magnet system would be considerably reduced in complexity and cost.

**Gyrotron and Advanced Millimeter Source Development:** Improved power levels and efficiency have been obtained in operation of the gyrotron device (electron cyclotron maser) developed at the Plasma Fusion Center. Output powers of 100 kW at a frequency near 140 GHz have been achieved at an efficiency of 36%. To our knowledge, this is the highest efficiency ever achieved at any frequency above 60 GHz by a high-power coherent radiation source, including masers or lasers. Operation powers of up to 175 kW at 28% efficiency have also been achieved. Operation is short-pulse (1 μs), and scaling to long-pulse and CW operation is now under way in industry. The output bandwidth has recently been measured on a single pulse basis and is found to be less than 3 MHz. Second harmonic emission (25 kW at 241 GHz) in the TE_{112} mode with 7% efficiency has recently been observed. A one megawatt, 120 GHz gyrotron has been designed and is under construction. It is expected to operate in 1986. The gyrotron group has also developed a tunable far infrared laser based on stimulated Raman scattering of CO_{2} laser radiation in CH_{3}F gas. Continuous tuning between 32 and 40 cm\(^{-1}\) (250 to 300 μm) has been achieved.

**APPOINTMENTS AND PROMOTIONS**

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

Appointments include: Dr. Vitale Berkman (Allis-Chalmers, Sala Magnetics Operation), appointed Electronics Engineer in the Mirror Confinement Division; Boris Blanter (MIT Laboratory for Nuclear Science), appointed Programmer/Analyst in the Mirror Confinement Division; Eric Georgelis (Magnetic Engineering Associates), appointed Mechanical Design Engineer in the Mirror Confinement Division; Dr. Stephen Goldberg (University of Wisconsin), appointed experimental Research Scientist in the Mirror Confinement Division; Dr. William Guss (TRW), appointed experimental Research Scientist in the Mirror Confinement Division; H. Lawrence Holcomb (Macquarie University), appointed RF Heating Engineer in the Mirror Confinement Division; Felix Kreisel (RCA), appointed VAX/VMS Systems Specialist in the Toroidal Confinement Division; Dr. R. Alan Cuomo (ORNL), AC losses in ICCS conductors; Dr. Zengji Guo (Academia Sinica, PRC), tokamak edge-plasma effects; Dr. Charles Curtis (University of Arizona), edge-plasma effects; Dr. John Davies (Clark University), theory of free electron lasers; Dr. Vladimir Fuchs (IREQ), fusion theory and computations; Dr. Andrew Hudor (University of Arizona), mode conversion theory; Dr. Elizabeth Killne (Joint European Torus), soft X-ray emissions and fluctuation studies; Dr. Andrew Hudor (University of Arizona), mode conversion theory; Dr. Elizabeth Killne (Joint European Torus), soft X-ray emissions...

The Plasma Fusion Center has also hosted several Visiting Scientists in the various research programs. They are: Dr. Gerhard Berge (University of Bergen, Norway), fusion theory and computations; Dr. R. Alan Cairns (University of St. Andrews), mode conversion theory; Dr. Franklin Chang (NASA), plasma propulsion; Dr. Charles Curtis (University of Arizona), edge-plasma effects; Dr. John Davies (Clark University), theory of free electron lasers; Dr. Vladimir Fuchs (IREQ), fusion theory and computations; Dr. Tsuneyuki Fujii (Osaka University), lower hybrid experiments on Alcator C; Dr. Hiroyuki Fujita (University of Tokyo), AC losses in ICCS conductors; Dr. Zengji Guo (Academia Sinica, PRC), tokamak fusion technology and engineering; Dr. Michael Hayes (Dartmouth College), Versator ECRH program; Dr. Shingi Hiroe (ORNL), TARA X-ray measurements and fluctuation studies; Dr. Andrew Hudor (University of Arizona), mode conversion theory; Dr. Elizabeth Källne (Joint European Torus), soft X-ray emissions...
from Alcator C; Dr. Jan Källne (Joint European Torus), soft X-ray emissions from Alcator C; Dr. Peter Laurence (Courant Institute of Mathematical Sciences), fusion theory and computations; Dr. Hirobumi Saito (Japanese Institute of Space and Astronautical Science), high-power gyrotrons; Dr. Frederick Seguin (American Science and Engineering), impurity transport and MHD phenomena in Alcator C; Dr. Abhijit Sen (Physical Research Laboratory, India), theory of free electron lasers; Dr. Richard Slusher (Bell Laboratories), CO$_2$ laser scattering from lower hybrid waves in Alcator C; Dr. Clifford Surko (Bell Laboratories), CO$_2$ laser scattering from lower hybrid waves in Alcator C; Dr. Han S. Uhm (Naval Surface Weapons Center), theory of beam-plasma systems with intense self fields; Dr. Yuan-Zhao Yin (Academia Sinica, PRC), free electron lasers; and Dr. Fei-Ming Zhao (Harbin University, PRC), plasma-wall interactions in Alcator C.

**GRADUATE DEGREES**

During the past year, the following students graduated with theses in fusion-related areas: Frank Camacho, S.M. in Electrical Engineering and Computer Science; James Doyle, Ph.D. in Nuclear Engineering; William Ijmas, S.M. in Nuclear Engineering; William Marable, Ph.D. in Nuclear Engineering; F. Scott McDermott, Ph.D. in Physics; Jeffrey Parker, Ph.D. in Physics; Pasquale Rezza, S.M. in Mechanical Engineering; Roger Richardson, S.M. in Electrical Engineering; John Schutkeker, S.M. in Nuclear Engineering; Thomas Shepard, S.M. in Electrical Engineering and Computer Science; Thomas Warner, Ph.D. in Electrical Engineering and Computer Science.

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 1945 as the natural continuation of the wartime Radiation Laboratory. Initially, the Laboratory 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, the Laboratory has branched out into a number of directions, and in fact has been the root from which many other laboratories at MIT have grown. Research in the Laboratory 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, there have been approximately 250 graduate students together with 100 undergraduates working on research projects within the Laboratory. Major support for this research is derived through the Joint Services Electronics Program (JSEP) of the Army, Navy and Air Force, as well as 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 the Laboratory is very heterogeneous in character, it can be seen as being organized into two major thrusts focused on electronics and optics, and language, speech and hearing. In addition, there are seven smaller areas of focus as well as some individual activities which have a small amount of coupling to other projects within the Laboratory.

ELECTRONICS AND OPTICS

In this area, research ranges from the production and characterization of electronic materials to processing techniques, device physics, high performance integrated circuit design, and architectural considerations for specialized systems. The Laboratory, in this area, brings together experts in physical chemistry, condensed matter physics, electronic materials, device design and characterization, processing innovation, design techniques for complex high performance integrated circuits, and architectural strategies for a variety of special purpose application areas which include digital signal processing and image processing.

Professor Sylvia T. Ceyer has finished the construction of a molecular beam ultra-high vacuum surface scattering apparatus to study the reaction dynamics of fluorine atoms on silicon surfaces. Using this apparatus, she has studied last bond formation on the surface as well as the desorption step, dominant features of the potential energy surface such as exit channel barriers, and other features of chemical reaction dynamics on semiconductor surfaces in general. During this period, Professor Keith Nelson has carried out the first picosecond, time-resolved observations of laser-induced ferroelectricity in several technologically important ferroelectric crystals. These studies of an important class of structural phase transitions demonstrate the possibility of high efficiency, ultra-high speed optical switching and modulation. Additionally, crystal lattice vibrations at terahertz frequencies have been induced, opening the possibility to watch molecules vibrate and undergo vibrationally driven chemical reactions.

In the Submicron Structures Laboratory, under the direction of Professor Henry I. Smith and Principal Research Scientist John Melngailis, very small structures and devices continue to be aggressively fabricated, including the smallest silicon field effect transistor ever built which has a channel length of 60 nanometers. At this channel length, velocity overshoot was observed. Silicon devices were also made in which quantum mechanical superlattice effects and one-dimensional conductivity were observed for the first time. Dr. Melngailis has introduced a new research program using a focused ion beam to restructure and repair integrated circuits. Ion-assisted deposition of tungsten and carbon has also been demonstrated. This has led to new and important techniques for both optical and x-ray mask repair. Professor Carl Thompson has focused on the control of microstructure in thin metallic and semiconductor films. Through the control of surface energy-driven secondary grain growth, large grains can be obtained with grain boundaries positioned in such a way as to provide extremely high resistance to electromigration and thermally induced beading.
In the optics research area, Professor Erich Ippen has demonstrated several novel techniques for measurement on a femtosecond time scale. These techniques have provided the first measurements of femtosecond polarization dephasing in organic dye molecules. Professor Hermann Haus has become interested in the fabrication of wave guide arrays in materials compatible with active devices such as indium phosphide. This work brings into practice improved theoretical techniques for sampling with multiple coupled wave guides and is leading to the integration of optical techniques with conventional semiconductor electronic systems. Professor Clifton Fonstad has also provided a new wave guide analysis technique for semiconductor-guided wave optic structures, and has provided new capabilities using molecular beam epitaxy crystal growth techniques for use in making the heterostructures needed for these devices. The eventual goal of these projects is to produce monolithic sources of picosecond duration optical pulses and to develop modulators, multiplexers, and demultiplexers to encode trains of these pulses at multi-gigabit per second data rates. This year, Professor James Fujimoto has joined the faculty in the area of optics and quantum electronics, and has begun to develop new techniques in the investigation of high-speed optical and electronic processes in a variety of materials and systems. In collaboration with Professor Ippen and Professor Nicolaas Bloembergen of Harvard University, he has demonstrated the first measurements of non-equilibrium electron temperatures in metals. Finally, Professor Peter Wolff is continuing his studies of fundamental infra-red nonlinear processes in semiconductors.

In the condensed matter physics area, both theoretical and experimental studies have yielded new insight into a variety of novel states of matter. Professor A. N. Berker, using both prefacing transformations and and renormalization-group transformations, has completed phase diagrams for the epitaxial adsorption of oxygen on nickel (100). Further studies of selenium chemisorbed on the nickel (100) surface have led to a new phase diagram and a re-interpretation of existing experimental results. Working with Professor John Joannopoulos, structural phase transitions of the silicon (100) surface as a function of temperature have also been predicted. This shows two distinct families of geometries that can exist on the surface. Professor Joannopoulos has elucidated the aluminum-gallium arsenide interface in a Schottky barrier system and has provided new techniques for predicting the migration paths of aluminum atoms on the gallium arsenide surface. This demonstrates that aluminum atoms replace substrate gallium atoms and form aluminum arsenide bonds in the interface region which corresponds with a global minimum of the total energy. In a highly productive collaboration, Professor Patrick Lee has provided fundamental theoretical understanding of conduction mechanisms to help explain transport phenomena in very small one-dimensional MOSFETs. Experimental investigation of these devices has been carried on by Professor Marc Kastner, and the fabrication of the devices has been provided by Dr. Melngailis working in the Submicron Structures Laboratory. At low temperatures, a situation arises in these devices in which the entire device current is limited by a single microscopic quantum state. This leads to a new set of conduction phenomena which have been interpreted theoretically by Professor Patrick Lee in terms of variable range hopping. Professor Robert Birgeneau has been studying phase transitions of monolayer rare gas crystals physisorbed onto the basal planes of graphite. Remarkably, it has been shown that an incommensurate overlayer exhibits a continuous transition from an aligned to a rotated phase as a function of lattice mismatch.

In the area of VLSI circuit design, Professor Lance Glasser has invented a new ultraviolet write-enabled memory. He has also derived new techniques for the optimization of transistor sizes in an integrated circuit. Professor John Wyatt has extended previous results in waveform bounding which has led to a tightening of the bounds that were discovered earlier, as well as a new method for extending the results to include both bipolar and MOS circuit types. Professor Jonathan Allen has worked on new procedures for performance-driven circuit synthesis techniques, and new techniques for the generation of regular structures. In this work, the goal has been to generate integrated circuit layouts from a functional description which includes performance constraints, thus avoiding an analysis of final circuit layout to determine circuit performance.

There is a large, coordinated effort in research on speech and hearing. This effort unites contributions ranging from auditory physiology to auditory psychophysics, speech communication, and linguistics. Professor Kenneth Stevens has derived new models that simulate some aspects of signal processing by the peripheral auditory system which have interesting applications to speech recognition. Dr. Joseph Perkell has completed a study on co-articulation of lip rounding, and has also completed a novel quasi-static magnetic field movement transduction system which permits the study of articulator movements that cannot be directly observed. Professor Victor Zue has developed a
very large database for speech research that incorporates a vast amount of acoustic phonetic knowledge. This database can be accessed by a high-performance phonetic work station that will enable investigators to perform complex queries of critical importance to the development of advanced speech recognition systems.

Research on hearing and touch is being conducted by Professor Louis Braid, Senior Research Scientist Nathaniel Durlach, and Principal Research Scientist Steven Colburn. These studies of auditory perception are leading to new models of spectral shape perception and binaural interaction. New techniques of multi-band amplitude compression and frequency lowering are being used in advanced designs for hearing aids, and speech of exceptional clarity is being analyzed with a view toward improved signal processing schemes. Work on tactile communication of speech has demonstrated that good speech communication is possible through the tactile sense, and those characteristics which are essential for good tactile display are being identified.

In cooperation with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary, many long-range studies on the mechanism of hearing are being pursued. Dr. John Guinan has been studying efferent control of the muscles in the middle ear in response to intense sound through reflex action. Professor William Peake has been performing a comparative study of middle ear structures including the one-middle-ear-bone-type found in birds and reptiles, in contrast to the three-middle-ear-bone found in mammals. By studying ten different species, insight into the general structure/function relationship of the middle ear will be obtained. Professor Thomas Weiss is studying the alligator lizard to derive a model of the inner ear which includes a study of the relation between spike discharges of cochlear neurons and the receptor potential of cochlear hair cells. In this way, the overall transduction process from fluid motion in the inner ear to spike potentials on the auditory nerve is being characterized. Professor Nelson Kiang has been studying the way in which speech is coded in discharges of intracochlear nerve fibers. For many years, the encoding relations in the auditory nerve were studied in terms of simple stimuli such as impulses and sine waves, but it is now becoming feasible to use speech-like stimuli so that there is increasing interaction between this area of fundamental research in auditory physiology and new models for incorporation into automatic speech recognition systems. During this past year, a new laboratory has been set up by Dr. Donald Eddington for the clinical study of multi-electrode intracochlear implants which will be studied in a number of human subjects. New techniques for portable signal processing are being developed in order to transduce the acoustic speech signal in the subject's environment to stimulating waveforms appropriate for the implanted electrodes.

FOCUS AREAS

Atomic and Molecular Physics

Professor Shaoul Ezekiel has been studying a number of systems involving atomic and molecular collisions in interactions of atoms in fields. These have been particularly important with respect to the derivation of high-precision time standards, as well as passive resonator gyroscopes based on the Sagnac effect. Professor Daniel Kleppner has exhibited techniques for turning off spontaneous emission by placing atoms in a cavity that has no mode at the natural frequency of interest. This is the first time that such an effect has been seen, thus allowing the modification of spontaneous emission which is important for radiation detection in high-precision measurements. Professor David Pritchard is building up substantial new experimental apparatus for an ultra-sensitive detector used to detect individual ions in a Penning trap, and ultimately to perform ultra-high precision mass spectroscopy. The advent of these new, ultra-precise mass measurement techniques will permit the resolution of many outstanding questions in physics, including the possibility of weighing a chemical bond.

Plasma Physics

A major new effort has grown during the past year in the study of free electron lasers as a source for intense millimeter and sub-millimeter wavelength electromagnetic radiation. Professor George Bekafi has demonstrated frequency tuning and amplifier gain as a function of the electron beam energy, beam current, and wiggler strength. Work is now in progress on the design of a tunable, one-ten micron wave length free electron laser. This is a major new research project oriented toward the demonstration of compact, high-intensity radiation sources. Professor Bekafi is also collaborating with Professor Miklos Porkolab on a number of experiments utilizing the Versator II tokamak. This facility is used with primary emphasis on basic investigations of RF plasma heating and current drive.
In particular, newly upgraded capabilities of Versator II include the ability to run fully RF-driven plasmas without ohmic heating. Significant increases in plasma density have been achieved and a number of new current drive schemes have been explored.

In the area of theoretical plasma physics studies, Professor Abraham Bers has conducted a number of theoretical investigations dealing with the intrinsic dynamics in lower-hybrid current drive, new phenomena in induced stochasticity that may lead to means for creating confining potentials in tandem mirrors, and schemes for millimeter wave signal generation by cyclotron-harmonic maser action. Professor Bruno Coppi has contributed a number of theoretical studies for the ALCATOR and Versator tokamaks, including important insights on the current density profile arising from pellet injection into the torus. Several other collaborations have led to numerous theoretical insights valuable to the design of large plasma facilities.

Radio Astronomy

Professor Bernard Burke has been continuing his studies of extra-galactic radio sources using the Very Large Array, and the Very Long Baseline Interferometer. This has led to the discovery of new lensed quasars which reveal a great deal about cosmology and the distribution of matter on the largest scales. In addition, work continues on a large-scale survey of radio sources over a large region of the sky, addressing such questions as the radio luminosity function, large-scale clustering, and radio source evolution. Professor Jeffrey Lang has been studying the control and estimation of large flexible structures, particularly space structures such as antennas. He has been able to accurately characterize the structure dynamics and to provide excellent tracking capability, both in a theoretical model and a laboratory-scale flexible space structure. Professor David Staelin has demonstrated for the first time the use of two-color astrometric interferometric techniques that will yield improvements of at least a factor of three in the estimated separations between stars. A new interferometer, with a twenty-meter baseline, is now under construction at the Mt. Wilson Observatory for further observations of this type.

Image Processing

The advanced television research program, led by Professor William Schreiber, is investigating a wide variety of topics aimed at the provision of very high resolution television images. This work has included fundamental studies in motion-compensated interpolation, motion rendition, and adaptive sharpening of color pictures. A new simulation facility for high definition television is being built. Professor Staelin has been studying filters for sampling and reconstructing video images in space and time in order to minimize perceived errors. Professor Jeffrey Lang and his students have developed very large-scale integrated circuits for use in high definition television, concentrating on the study of three-dimensional interpolation. These circuits are now being fabricated. The architecture of interactive graphics work stations, and the associated image processing problems contained in such systems, is being studied by Professor Donald Troxel. A new polygon shading algorithm for raster displays, which approaches the quality of computer images, has been developed and is yielding high-quality images at low computational cost.

Digital Signal Processing

In the digital signal processing area, Professors Alan Oppenheim and Jae Lim have been focusing on applications in speech processing, image processing, and underwater acoustics utilizing new algorithms that integrate numerical and symbolic methods. Image reconstruction from a single threshold crossing has been both demonstrated and theoretically analyzed, as well as several systems designed to augment traditional numerical signal processing techniques with symbolic techniques that are useful for signal understanding and characterization. Professor Bruce Musicus has been focusing on highly parallel algorithms for digital signal processing including special purpose computer architectures. New insights into computer architectures for computer vision have been obtained by utilizing relaxation algorithms in a highly distributed manner.

Electromagnetics

Professor Jin-Au Kong and his students have continued studies of electromagnetic wave theory with applications to micro-strip antennas, micro-electronic integrated circuits, geophysical subsurface probing, microwave remote sensing, and transient electromagnetic pulse propagation problems. During
this past year, electromagnetic wave propagation in integrated circuits has been studied in relation to the problem of providing high performance interconnection between computer circuits with minimum distortion and cross-talk. Professor Frederic Morgenthaler has continued his studies aimed at the understanding of electromagnetic, magnetostatic, and magneto-elastic wave phenomena as utilized in novel device concepts useful for microwave signal processing applications. He has also been studying the utilization of microwave hyperthermia, and has developed a new microwave applicator for this purpose.

Communications

Professor Jeffrey Shapiro has been studying the use of atmospheric optical communications in local area networks, has been working towards the development of light sources with reduced quantum noise, and has been developing system theory for multi-function coherent laser radars. During this last year, he demonstrated the existence of phase-sensitive noise in the output of a dye laser pumped sodium vapor cell. This noise did not go below the semi-classical shot noise limit, but is an important preliminary to the generation of squeezed state light. Dr. Robert Rediker has been building a coherent ensemble of diode lasers to produce high-power, highly reliable systems with a narrow spectral line and highly directional single-spatial mode. These techniques may also be used for very low power applications involving the storage of very large amounts of data.

The Neurophysiology Laboratory, led by Professor Jerome Lettvin, has discovered a new phenomenon called "Demasking" in which various elements in the field of vision can mask each other. These results may have significant applications in the understanding of the reading process, both in normal and dyslexic subjects. A new account of color vision has been developed which requires the conception of a central mechanism to explain the range of effects observed. In addition, a new electromechanical transducer in cell membranes has been discovered and modeled, providing an extremely fast and general control on many kinds of membrane processes.

JONATHAN ALLEN
INTRODUCTION

When the books closed on June 30, cash received from gifts, grants, bequests, and membership in the Industrial Liaison Program (ILP) exceeded $68 million. This total was 23 percent higher than in fiscal year 1984.

Also during the year, discussions among members of MIT's Corporation and central administration focused on ways to increase the size of the Institute's capital base. Chief concerns were finding new methods for increasing capital to support faculty salaries, research and teaching, and undergraduate and graduate student aid; and expendable funds for unrestricted purposes. In a report to the Corporation Development Committee, Paul Gray and David Saxon said:

In recent years MIT has become increasingly concerned with building a strong capital base, to ensure our future as the world's leading science-based research university. If we look at the quality of MIT--our faculty, students, research and educational programs--we are arguably second to none. Yet if we look at our level of endowment, we are severely undercapitalized in comparison with such universities as Columbia, Harvard, Princeton, Stanford, and Yale. For example, Harvard University has a level of endowment that is four times its operating budget, while MIT's endowment and operating budget are essentially the same size. This undercapitalization must be corrected if we are to attract the best possible students and faculty, and stay at the cutting edge of education and research.

Talks culminated in the decision to undertake a funding drive, known as the Advance Initiative, as the start-up effort for a proposed major capital campaign. The Advance Initiative has a goal of $100 million, to be raised by December 31, 1986. Its focus is on increasing the Institute's endowed and expendable unrestricted funds, and receipts will be included in the nucleus fund for the subsequent campaign. In fiscal year 1985 the Advance Initiative raised $35.8 million in gifts and pledges: $29.2 million for endowment, and $6.6 million for expendable unrestricted purposes.

Proposed purposes and dollar goals for a possible capital campaign were under consideration throughout the spring. Discussions will continue during the coming year, as will identification and screening of potential donors.

PRIVATE SUPPORT

Private support for 1984-85 totaled $68.5 million, including the following: $61.7 million in gifts, grants, and bequests, and $6.8 million in support through membership in the ILP. The total compares with $55.7 million in 1984, $56.4 million in 1983, $46.6 million in 1982, and $47.5 million in 1981. Gifts-in-kind for the past year (principally gifts of equipment) were valued at $9.8 million.

Sources of gifts for fiscal year 1985 were: alumni, $12.8 million; non-alumni friends, $4.0 million; corporations, corporate foundations, and trade associations, $17.6 million; foundations and charitable trusts, $26.6 million; others, $0.6 million. Included in the totals for alumni and friends are gifts of $1.3 million made to the Rogers, Maclaurin, and Compton Pooled Income Funds. The total income of $6.8 million for corporate liaison programs represented a 2.9 percent increase over the total for fiscal year 1984.

Donors designated expendable and endowed funds as follows: unrestricted, $11.8 million; departments, $21.8 million; faculty salaries, $7.4 million; graduate student aid, $5.0 million; undergraduate student aid, $2.8 million; building construction funds, $3.8 million; other funds, $9.1 million.

Included in the totals above was support for thirteen new endowed chairs--six full professorships and seven career development professorships--as well as four term chairs.
CORPORATION DEVELOPMENT COMMITTEE

The annual meeting of the Corporation Development Committee (CDC) was held on November 1st, presided over by Chairman David S. Saxon, and attended by 59 members. Speakers included MIT President Paul Gray and Alumni Association President Mary Frances Wagley '47. Attendees also visited five campus locations for updates on some of MIT's top priority programs. The choices: Department of Economics, Project Athena, Center for Real Estate Development, Artificial Intelligence Laboratory, and the Microelectronics Program (VLSI).

The Dalton Award for service to MIT was made to Yaichi Ayukawa '52, a member of the CDC since 1974 and a member of the Corporation since 1977. He was commended for three decades of service to the Institute and for his invaluable guidance and counsel.

SPECIAL GIFTS

With further progress on campaign planning, and a clearer sense of emerging internal priorities, the Special Gifts office was restructured. Many of the responsibilities of the Major Gift office--prospect identification, evaluation, and some cultivation functions--were assigned to district directors in Leadership Gifts. Management of the existing inventory of major gift prospects will rest with Nelson C. Lees, director of Resource Development and Special Gifts, and G. Rodger Crowe, director of the Development Office.

Leadership Gifts

Director Edith E. Nelson and the Leadership Gifts staff continued to work closely with volunteers in the identification, cultivation and solicitation of gifts from individuals. The National Resources Program (screening) initiated in June of last year continued to expand. With the support of CDC members, sessions were held in Houston, hosted by Joe F. Moore '52; New York, hosted by Denis A. Bovin '69; Philadelphia, hosted by Hal L. Bemis '35; Chicago, hosted by F. Richard Meyer III '42; and San Francisco, hosted by Denman K. McNear '48. Two sessions were held in Boston, hosted by D. Reid Weedon, Jr. '41.

Plans for next year's program focus on cities with large alumni concentrations and/or rapid financial and industrial development. To date approximately six thousand prospective alumni donors have been screened. In the months ahead, district directors, other Resource Development staff, and volunteers will continue to follow up these prospects for further information, cultivation, and solicitation.

The Sustaining Fellows program continued its mission of recognizing, involving, and cultivating major Institute benefactors. Membership grew to 890: 551 life members and 339 annual members. Breene Kerr '51 continued his effective chairmanship.

On December 11, 1984, the Sustaining Fellows program held a gala event on campus at Walker Memorial, celebrating the program's fifth anniversary. Over 250 guests attended a black tie dinner, with CBS News White House Correspondent Lesley Stahl as the keynote speaker. Miss Stahl shared her insider's views of the Presidency and politics.

Each year the unrestricted Sustaining Fellows fund is allocated by the president of MIT. The 1984-85 fund, totaling approximately $350,000, has been committed to the East Campus physical renovations project ($200,000) and to the development of educational initiatives ($150,000).

During the year an extensive review of Sustaining Fellows membership requirements was undertaken. Effective July 1, 1985 the annual membership requirement will be increased from $2,000 to $3,000 for individuals making gifts for unrestricted purposes, endowment, professorships, or student financial aid. Matching gifts from corporations will no longer be counted toward such gifts. Life membership will continue to require cumulative gifts of $25,000 for any purpose. Response to these changes has been positive to date.

DEVELOPMENT OFFICE

Under the leadership of G. Rodger Crowe, the Development Office continued its staff support of major fundraising priorities and intensified its prospect identification and research efforts within the context of the Advance Initiative and campaign
planning process. Working closely with Resource Development staff and the leadership of various schools and departments, the Development Office provided clearance, background information and advice in support of priority fundraising efforts, including Project Athena, REMERGENCE, the brain sciences, and the Chemical Engineering Unit Process Laboratory.

Continued progress was made in the use of commercial data bases for identifying and researching prospective donors--individuals, corporations and foundations.

HEALTH SCIENCES

Health Sciences development activities have increased greatly this past year. Major new gifts were received to support faculty, graduate students, and postdoctoral fellows engaged in the fields of brain science, molecular biology, and biomedical engineering.

Barbara Gunderson Stowe, director of Health Sciences Development, worked closely with individual faculty members and faculty committees to secure support for a variety of the Institute's health-related projects, laboratories, and programs. Critically important to this endeavor was the leadership provided by Kenneth A. Smith, associate provost and vice president for research, and Dean Emeritus Irwin W. Sizer.

COMMUNICATIONS

The Office of Communications, under the direction of Deborah J. Cohen, produced several publications including: the 1985 Factual Profile; an expanded CDC News; and Japan and MIT. Staff members also consulted with groups throughout the Institute on various departmental publications, and a large number of proposals were issued for Institute fundraising priorities.

Donor relations activities concentrated on improving contacts with donors through reports and campus visits. A system for monitoring these contacts, incorporating information from throughout the Institute, began operation. Reporting on endowed professorships was stepped up, and a well-received program of campus visits continued. In conjunction with the Student Financial Aid Office, staff members continued to monitor reporting to financial aid donors.

FOUNDATIONS AND CORPORATIONS

In its first full year of operation the Office of Foundations and Corporations, under the direction of Vincent C. DeBaun, was successful in attracting major grants for curriculum revision in the Department of Electrical Engineering and Computer Science; internships in the MIT/Japan Science and Technology Program; and endowed fellowships in the brain sciences. The office also had a vital role in attracting additional grants from private foundations and corporations for Institute priorities such as junior faculty support, equipment in biomechanics research, fellowships in acid rain research, and undergraduate financial aid.

The National Business Committee (NBC), chaired by Robert L. Mitchell '47 and directed by Robert Hagopian, continued as a key factor in the work of the Office of Foundations and Corporations. Since the NBC seeks new corporate interactions with MIT, much of its activity centered on the Industrial Liaison Program; thirty new ILP solicitations were made via NBC introductions, resulting in five new memberships. Decisions for the remainder are pending. Additional visits were initiated for support of the Martin Design Center, Sloan Sponsors Program, Materials Processing Center Collegium, and the Construction Affiliates Program, as well as to introduce the Institute's senior officers to high level business executives for cultivation purposes.

In the year ahead the Office of Foundations and Corporations will continue to expand its interaction with members of the CDC and NBC; undertake a widening agenda of projects with the counsel and participation of deans, department heads, and senior faculty; and seek out additional opportunities for cultivation and stewardship activities.

INDUSTRIAL LIAISON

During the past year, the Industrial Liaison Program again posted new levels of membership and of service to companies and to MIT faculty and departments. Directed by Professor James M. Utterback, the program showed a net gain of 14 paying members,
and cash flow exceeded $6.8 million. Total membership now stands at 308, of which 284 are paying members and 23 are affiliate members based on major gifts to the Institute.

Highlights of the year included the awarding of Silver Medals, to the MIT Report and to the program's new series of videotaped research briefings, by the Council for the Advancement and Support of Education (CASE).

**Member Services**

Outstanding meetings were conducted jointly with the research program on the "Future of the Automobile," with the Sloan School of Management on "Managing the Transition to Fifth Generation," and with Project Athena on the first year's results. Attendance at these three meetings totaled more than one thousand. A meeting for senior executives was held in London on "Technological Ventures and Corporate Development." The National Academy of Engineering (NAE) and the Liaison Program jointly conducted a meeting at MIT on "Technology and Risk" in honor of Edward E. David, Jr., recipient of the 1984 NAE Bueche Medal.


**Program Organization**

During the year the program was reorganized along three industry sector lines: mechanical- and materials-based manufacturing; electronics and computation; and chemistry and biology manufacturing. One purpose of the group structure is to tailor the program's services more closely to company needs. Another is to provide training and continuity of service to member companies. Two promotions were made to implement the new organization: that of Kay Tamaribuchi from assistant director to associate director and of Thomas Moebus to assistant director. The three groups of officers are headed by Cynthia Bloomquist, Frederick Gross, and Thomas Moebus respectively.

With the reorganization, marketing and development efforts are also being increased. Emphasis is on building the number of U.S. firms which are program members. Marketing is expanding into industry sectors other than manufacturing, and new memberships during the year have included companies in areas such as banking, regional development, retailing, and publishing. The program continues to work closely with the staff of Resource Development in quickening its growth.

**ORGANIZATIONAL AND PERSONNEL CHANGES**

In the Development Office, Karen A. Engelbourg was appointed to the position of assistant director, effective July 30, 1984. In Communications, Patricia E. Harrison was promoted to associate staff writer.

Gail M. Masci, formerly recorder-coordinator in the Registrar's Office at Boston University, joined the Leadership Gifts staff in March. She will provide additional computer processing support for the National Resources Program. Elaina M. Myrinx, formerly director of the International Clan (alumni clubs) Network at Carnegie-Mellon University joined the Leadership Gifts staff October 1 as district director. In June she assumed responsibilities for the West Coast.

Edith E. Nelson resigned the position of director of Leadership Gifts, effective June 30, 1985, but will be continuing with the department in a consulting capacity. Thomas W. Boyden, Major Gifts officer, resigned to pursue other interests, effective June 30. Stephen D. Immerman, district director for the South and Southwest region resigned to assume duties in the Office of the Senior Vice President, effective January 1.

In the Industrial Liaison Program, Kay Tamaribuchi, who was previously assistant director, was named associate director. Thomas Moebus was promoted to assistant director; David Lampe was formally named editor of the MIT Report, and Lucie Juneau was promoted to the position of assistant editor. The following new officers were
appointed: Douglas Carlson, Marc Chelemer, Christopher Dippel, Diana Garcia-Martinez, Susan Lee, Kevin Lonnie, David Woodruff, and Sandra Yulke. Jennifer Knapp-Stumpp was given a leave of absence.

Also during the year, John Preston resigned to become president of Visual Communication Network, Inc. (VCN), and Laura Scott-Stout resigned to become VCN's director for European business and vice president. Katherine Van Sant resigned to return to the Washington area, and Douglas Carlson resigned to accept a position with W.R. Grace.

CONCLUSION

With the continuation of the Advance Initiative and of planning for a capital campaign, the tempo will accelerate in the coming year. Before we move on, I know I speak for all my colleagues when I take a moment to acknowledge the fifty years of service by Dean Irwin W. Sizer. During the past decade, Dean Sizer has focused his prodigious energies on support for the health sciences, and has been most effective. We are fortunate that he will continue as president of the Whitaker Health Sciences Fund, with his office at MIT's Whitaker College.

SAMUEL A. GOLDBLITH
Lincoln Laboratory

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 96 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1985 the operating budget was $292 million, supporting the efforts of 825 professional staff, 78 percent of whom hold advanced degrees.

Several administrative changes at the Laboratory Steering Committee level occurred during the year. John A. McCook succeeded Henry W. Fitzpatrick as Assistant Director. Paul R. Drouilhet succeeded Daniel E. Dustin upon his retirement as Assistant Director. Dr. John A. Tabaczynski became Associate Head of the Radar Measurements Division upon the resignation of Dr. John Rheinstein from that position. William P. Delaney succeeded Mr. Drouilhet as Head of the Surveillance and Control Division, and Carl E. Nielsen, Jr., became Associate Head. Dr. Glen F. Pippert retired as Head of the Optics Division, and will be succeeded by Dr. Charles W. Niessen, who transferred from the position of Associate Head of the Communications Division to serve as Associate Head of the Optics Division. Dr. Darryl P. Greenwood also became an Associate Head of the Optics Division. Dr. Frank W. Floyd succeeded Dr. Niessen as Associate Head of the Communications Division. Dr. V. Alexander Nedzel passed away during the year and was succeeded as Head of the Aerospace Division by Dr. Herbert Kottler. Vincent Vitto succeeded Dr. Kottler as Associate Head.

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.

STRATEGIC DEFENSE TECHNOLOGY

The Laboratory has worked on ballistic missile defense (BMD) for over 20 years. The major program elements are discrimination physics, algorithm development, field measurements, and hardware/technology development.

The Laboratory works in a number of technology areas which have immediate or long-range applicability to BMD measurements or systems. Technology efforts include the development of advanced signal and data processing devices and systems as well as the millimeter-wave transceiver work described in the following section.

MONOLITHIC MILLIMETER-WAVE TECHNOLOGY

The Laboratory has successfully completed a multi-year effort establishing the feasibility of an analog monolithic GaAs circuit technology suitable for radar components at millimeter-wave frequencies. The design, fabrication and testing of monolithic GaAs circuits to accomplish amplification, frequency multiplication, phase control, switching and heterodyne receiver functions have been demonstrated.

The fabrication of high frequency diodes and field effect transistors along with transmission lines and circuit elements on semi-insulating GaAs substrates has been accomplished through advancements in GaAs fabrication technology. A multi-chip monolithic array radar transceiver has been assembled through the realization of functional semiconductor chips of typical dimensions of 0.2" x 0.1" x 0.007". The frequency of operation has been extended over a wide range of frequencies in the millimeter-wave band by scaling the circuit dimensions and using frequency multiplexers and heterodyne receivers.

Use has been made of a reactively sputtered Ta2O5 capacitor developed at the Laboratory to achieve circuit area reduction as a result of the high dielectric constant material. In addition, active device modeling and characterization as well as improved circuit design and measurement techniques have been developed in support of this effort. Monolithic fabrication of devices providing these first critical analog circuit functions permits the use of innovative semiconductor batch processing for complex microwave and millimeter-wave circuits. The potential for high volume and low cost production technology for high frequency analog components is expected to affect many radar and communication applications.

INTERSATELLITE LINKS USING OPTICAL HETERODYNE TECHNOLOGY

For several years the Laboratory has been developing the technology base required for realizing small, efficient intersatellite communication links. Both the transmitter laser and the local oscillator at the receiver utilize a single spacial mode, single frequency GaAlAs CW laser. Frequency modulation of the
transmitter laser diode is accomplished by direct current injection. The heterodyne receiver, utilizing a pair of silicon PIN photodetectors, achieves a sensitivity close to the quantum limit. An end-to-end system operating at 100 Mbps and requiring 10 photons per bit has been demonstrated in the laboratory. Flight hardware will be built for a satellite demonstration in 1989.

**SATELLITE SURVEILLANCE RADAR SIGNAL PROCESSING**

Narrowband radars which are capable of tracking earth satellites represent an important resource related to both present and future space missions. In the satellite surveillance problem the signal-to-noise ratio becomes very low for distant satellites. Many seconds of radar data may be needed to receive enough signal energy to estimate target motion with sufficient accuracy to sustain the tracking operation. Over such time intervals many satellite trajectories are not accurately described by constant velocity motion assumptions, and small target rotation rates cause significant variation in apparent target reflectivity due to aspect angle change.

This combination of low signal-to-noise ratio and complex radar signal structure defines the signal processing problem in this application. It is possible to extend the popular digital matched filter bank algorithms to estimate the complex range motion of such targets, but the computing power required to execute the algorithm within real-time signal processing constraints increases rapidly.

To utilize the power of recently available commercial floating-point processors, the Laboratory has developed an advanced signal processing algorithm which requires less computing power and provides greater performance in this application than the usual extensions of the matched filter bank algorithms. Real-time maximum likelihood estimation of parameters characterizing changing target reflectivity and complex target range motion from noisy radar data has been realized using a linear sub-problem structure combined with modern numerical optimization techniques. Unlike existing signal processing algorithms which employ fast Fourier transform software to implement a matched filter bank, the new algorithm operates in the time domain with an execution time essentially proportional to the number of radar signal samples.

The first version of a signal processor based on the new algorithm has been installed at the Millstone Hill L-band satellite surveillance radar. It currently supports many tracking operations of the radar and, over a large class of satellite targets, approaches performance limits set by thermal noise levels in the radar receiver.

**INFRARED AIRBORNE RADAR**

The purpose of the infrared airborne radar program is to develop technology which utilizes coherent carbon dioxide laser imaging radars, both pulsed and cw, for ground observation under night-time and poor-visibility conditions. A transportable, ranging (pulsed) radar with 6 meters accuracy was developed several years ago to demonstrate component technology and test imaging concepts. This system has been upgraded to provide higher range accuracy, a doppler velocity imaging capability with a resolution of 1 m/s, as well as registered infrared and visible imaging capabilities. All data are recorded digitally for processing.

An airborne version of this basic system has been developed during the past two years and is being tested. A ranging capability with six meters accuracy has been demonstrated and upgrades similar to those of the truck-based system are in progress. This airborne sensor will permit evaluation of object detection as well as false alarm effects over a variety of terrains.

Investigations are continuing to develop automatic screening techniques in the various sensor dimensions, singly or in combinations, to provide automatic vehicle detection and identification. The data are also being investigated for potential applications in autonomous navigation.

**TWO-DIMENSIONAL LASER DIODE ARRAYS**

Recently, a novel technology has been developed which allows the fabrication of monolithic two-dimensional arrays of efficient diode lasers. Semiconductor diode lasers are well recognized for their ability to efficiently convert electrical power into intense radiation. However, nearly all efficient semiconductor lasers developed to date have been limited in output power and geometric flexibility because the lasers rely on the formation of high-quality mirrors by cleaving, that is, by breaking the substrate along certain crystallographic planes. Thus, only small individual devices with a few milliwatts of power or, at best, line arrays of lasers with somewhat increased total output, have been possible in monolithic structures. The new fabrication technology allows the fabrication of two-dimensional arrays over an entire wafer with emission either along or perpendicular to the substrate, thus promising substantially higher output powers and a broad new range of geometrical possibilities for integrated optical devices.

The new fabrication technique is based on a recently observed phenomenon of mass transport of InP wherein heat treatment at a temperature near, but below, melting causes the atoms near the surface to move and seek a configuration of lower surface energy. This phenomenon is employed to form three separate and essential features of the two-dimensional arrays. First, mass transport is exploited to form high-yield
arrays of efficient, buried heterostructure GaInAsP laser stripes. Next, nearly perfect mirrors are formed on the lasers by chemical etching and subsequent smoothing by mass transport. Finally, 45 degree mirrors are formed next to each laser to deflect the laser output upward, perpendicular to the substrate. In initial results with small arrays, a power density of 15 watts per square centimeter of substrate has been achieved; extension to large arrays with densities approaching 100 watts per square centimeter is anticipated.

The techniques for fabricating high-quality lasers and mirrors are potentially useful also for short coupled-cavity lasers as well as for monolithic integration of the semiconductor laser with optical and other electronic devices. A new dimension in laser technology is added by two recent demonstrations, one jointly with the campus, of techniques for phase-locking arrays of diode lasers to achieve coherent high power output.

FOCAL-PLANE IMAGE PROCESSING

Conventional image processing procedures for the extraction of features (e.g., edges, intensity, size) result in extremely large and complex hardware because the data transfer rates and computation loads are huge. The Laboratory's focal-plane processing concept is based on the realization that the detected analog image on the focal plane is in the ideal two-dimensional format for efficient parallel processing; what is required in addition is the capability to execute arithmetic operations essential for feature extraction from the image. The goal is to provide at each resolution element (pixel) the functions of addition, subtraction and multiplication, and the functions of convolution, correlation and histograming from a large array of pixels. Only essential features, extracted on the focal plane, would be transferred to the processor for higher-level image understanding operations.

As an example, a difficult image-processing task requiring a computation rate of $10^{12}$ operations per second is the convolution of an image with a Gaussian kernel function for the implementation of the difference-of-Gaussians edge extraction technique. At Lincoln, Gaussian convolution has been achieved on the focal plane of a charge-coupled imager by diffusing the charge in each pixel to the surrounding pixels. The width of the Gaussian kernel is electronically variable, and the operation is performed with a high degree of accuracy. The convolution is performed in real time during the blanking intervals in standard television cameras. The required hardware is greatly reduced in comparison to conventional methods.

Several other fundamental image-processing operations have been demonstrated on charge-coupled focal planes, including the extraction of intensity histograms of images, the nonvolatile storage of analog images, the subtraction of one image from another, and the ability to scan out an image with a focused optical beam. Appropriate combinations of such operations will be used for the implementation of a large variety of image processing functions. For example, the combination of optical detection, Gaussian convolution, analog memory, frame-to-frame subtraction, and pixel thresholding functions on the focal plane would suppress unwanted details in an ordinary image and provide only two-dimensional outlines of significant objects within the image. Such techniques should find application in real-time guidance, target identification, and robotic systems.

SPEECH PROCESSING

A new sinusoidal model for speech waveforms has been developed for use in speech coding. The amplitudes, frequencies, and phases of the component sine waves are estimated from short-time Fourier transforms using a simple peak-picking algorithm. Rapid changes in the highly-resolved spectral components are tracked using the concept of "birth" and "death" of the underlying sine waves. For a given frequency track, a cubic function is used to unwrap and interpolate the phase such that the phase track is maximally smooth. This phase function is applied to a sine wave generator which is amplitude modulated and added to the other sine waves to give the final speech output. The resulting synthetic speech preserves the general waveform shape of the original speech and is very close in perceived quality.

In the presence of noise the perceptual characteristics of the speech as well as the noise are maintained. High-quality reproduction was obtained for a large class of inputs, including two overlapping, superposed speech waveforms; music waveforms; speech in musical backgrounds; and certain marine biologic sounds. Preliminary experiments indicate that it is possible to code the sine-wave parameters at 8 kbps to achieve synthetic speech that is robust and of high quality. Research is currently underway to modify the coding algorithm for operation at lower data rates as well.

In addition to providing a viable approach to the mid-rate coding problem, the new analysis/synthesis system is ideally suited for performing speech transformations such as time-scale, pitch-scale and frequency modification. Furthermore, these operations can be performed such that the speech transformations are time-varying.
Lincoln Laboratory has been active in the development of new sensor technologies (e.g., radar, acoustic, seismic, IR and laser), and signal and data processors for these sensors. Currently a number of Laboratory programs are moving beyond signal processing into the interpretation of sensor data using techniques drawn from the field of artificial intelligence (AI), including:

1. Use of laser and passive IR imagery in the tactical battlefield to recognize various types of vehicles.
2. Use of high resolution radar images to identify objects in space.
3. Interpretation of weather radar data to detect hazards to aviation.
4. An automatic diagnostic system to check out a complex airborne platform and indicate action to be taken to repair faults in the system.
5. Automation of en-route air traffic control.

Given the growing importance of AI technology to Laboratory programs, a new group has been formed at Lincoln to work specifically on machine intelligence technology. The long range objective is to develop "intelligent systems" for a variety of applications. By providing a concentration of accessible AI expertise and development facilities within Lincoln, the initiation of new AI application efforts will also be facilitated.

The initial technical focus of the machine intelligence group will be in the areas of sensor data understanding, knowledge-based systems applied to the diagnosis and control of complex systems, and advanced computer systems development for MI applications. In the sensor data understanding area, imaging radar and IR sensors will be emphasized, with the objective of developing a system to recognize three-dimensional objects from the images. The sensors, objects being observed, and the environmental context in which the objects are being observed are unique and present new challenges in image understanding research.

Knowledge-based systems have proven to be very useful in emulating the problem solving behavior of human experts in their domains of expertise. The second area of emphasis for the machine intelligence group is the application of knowledge-based system technology to the diagnosis of complex electronic system performance. One application that will be pursued is the diagnosis of telecommunications network faults and recommendations for reconfiguring the network to achieve necessary levels of performance.

The third major focus is the development of advanced, highly concurrent computing structures capable of efficiently supporting tightly coupled symbolic and numerical processing. Major advances are needed in the areas of architecture, language design, and circuit technology to provide the improvement in processing power of greater than three orders of magnitude needed for real time, intelligent signal understanding systems of the future.
Secretary of the Institute and Secretary of the Corporation

The Secretary of the Corporation serves as the Corporation's annually elected Recording Officer and joint signatory with the President in the awarding of the academic degrees of the Institute. The Officers and Committees of the Corporation rely upon the Secretary of the Institute to provide a range of support for the operation of the Corporation and its Committees. This report summarizes the work of the Institute's governing body.

Corporation Membership

At the year's end the total of 99 members of the Corporation included 72 Active Members, 25 Life Members Emeriti, 1 Life Member-Elect due to assume office on August 18, 1985, and 1 Member-Elect due to assume office at the October 4, 1985 Annual Meeting of the Corporation. This compared with 96 Members at the close of the previous year. There were 25 individuals whose membership status changed during 1984-85 in a year in which the Membership Committee continued to engage in five-year planning to moderate the annual fluctuation in Corporation nominations and to maintain the strength of women and minorities in the Institute's governing body.

Chairman David S. Saxon's continuing concern for the fundamental quality of education and his lifetime of experience in building the quality of the University of California and in speaking out on issues of basic concern to higher education continued to bring added strength to M.I.T. in his second year in office. He has been responsible for significant improvements in communication and evaluation procedures. These included innovations in the operation of the Corporation and its Visiting Committees.

At its June 3, 1985 Meeting, the Corporation elected the following Members to Life Membership, effective July 1, 1985: Norman B. Leventhal, Class of 1938, Chairman, The Beacon Companies; and Harold J. Muckley, Class of 1939, Chairman and Chief Executive Officer, Partners Oil Company; and effective August 18, 1985, John S. Reed, Class of 1961, Chairman, Citicorp/Citibank N.A. Both Messrs. Leventhal and Muckley have served two previous consecutive five-year terms, and Mr. Reed has served a previous five-year term.

At its June 3, 1985 Meeting, the Corporation further elected the following Members to five-year terms, effective July 1, 1985: Samuel W. Bodman, III, Class of 1964, President, FMR Corporation; Joan T. Bok, Chairman, New England Electric System; Colby H. Chandler, Class of 1963, Chairman and Chief Executive Officer, Eastman Kodak Company; Michael M. Koerner, Class of 1949, President, Canada Overseas Investments, Ltd.; Christian J. Matthew, Class of 1943, Executive Vice President, St. Mary's Hospital and Medical Center Foundation, San Francisco; Robert J. Richardson, Class of 1954, President, Bell Canada Enterprises; Robert A. Swanson, Class of 1970, Chief Executive Officer, Genentech, Inc. At the same Meeting, Frank S. Wyle, Class of 1941, Founder Chairman, Wyle Laboratories, was elected to a continuing two-year term; and Karen L. Fulbright, Class of 1977, a 1985 doctoral degree recipient of the Department of Urban Studies and Planning, was elected for a five-year term, effective October 4, 1985.

In addition, E. Milton Bevington, Class of 1949, President and Chairman of Servidyne, Inc., assumed an ex-officio position on the Corporation by virtue of his selection as the 1985-86 President of the Alumni Association. In that position, he succeeds our fellow Member, Mary Frances Wagley, Class of 1947, effective July 1, 1985. The Corporation expresses its deep and abiding appreciation to Dr. Wagley for the added responsibility she has carried this past year as the first woman to serve as President of the Alumni Association. Her participation in the quarterly Meetings of the Corporation and the Visiting Committees for Psychology and Humanities are particularly appreciated. She has been a superb Alumni Association President.

The Corporation was saddened by the death of its eldest Life Member Emeritus, Gwilym A. Price, retired Chairman and President of Westinghouse Electric Corporation, in McKees Rocks, Pennsylvania on June 1, 1985, just three weeks short of his 90th birthday.

Mr. Price served as a Member of the Corporation for 33 years, including 30 years as a Life Member and extensive service on several Visiting Committees. In his passing, the
nation has lost a distinguished leader of industry and a statesman of the business community. We at M.I.T. have lost a devoted friend, who participated in extraordinary measure in the affairs of the Corporation and the Institute.

Expiration of term membership has cost the Corporation the formal services of Claude W. Brenner, Class of 1947, President, Commonwealth Energy Group, Ltd.; Shirley A. Jackson, Class of 1968, Member, Technical Staff, Bell Telephone Laboratories; Jean Riboud, Chairman, Schlumberger, Ltd.; William J. Weisz, Class of 1948, Vice Chairman and Chief Operating Officer, Motorola, Inc.; and David R. Wilson, Class of 1973, Director of Software Development, Tipnis, Inc. These retiring Corporation Members continue their association with the Corporation in many ways as members of various alumni, Corporation, and Institute committees. Their combined service as Corporation Members is a total of 37 years of trusteeship, and they will be sorely missed.

Under the Bylaws of the Boston Museum of Fine Arts (MFA), the President of M.I.T. annually appoints a representative from M.I.T. to serve on the MFA Board of Trustees. During the past year, the Institute's representative has been Dean Jean P. de Monchaux of the School of Architecture and Planning. Several Corporation Members also serve as MFA Trustees. Howard W. Johnson continued his service as Chairman of the Overseers of the MFA.

Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) made its report on its previous year's study of the cluster of long range issues involved in the problem of undergraduate enrollment imbalance. The Committee devoted the 1984-85 year to issues relating to the graduate student experience at M.I.T.

CJAC held an afternoon meeting with the senior officers of the Institute in the fall of 1984 and then met for two hours in six monthly 7:00 a.m. meetings over the next several months. The final report of the Committee on its deliberations dealt with the diverse nature of academic organization with respect to graduate education throughout the Institute, wide differences in perceptions held by students and faculty in each department, and efforts to develop a graduate student questionnaire survey for possible future use in highlighting the graduate student experience.

Once again, I wish to acknowledge the brilliant leadership of our Corporation Member, Claude W. Brenner, who served as Chairman throughout the year, and whose four years as Chairman since 1981 have been happy, constructive years of accomplishment. His earlier service as a Member began in 1979, when he became President of the Alumni Association. I also wish to acknowledge the strong staff support provided to CJAC by Elizabeth A. Gerber during the past year.

Dedications and Special Functions

The Corporation continued to carry prime responsibility for dedications of major facilities and many special functions. Notable ceremonies this year honored our fellow Life Members Emeriti, Cecil and Ida Green, on the occasion of the Twentieth Anniversary of the dedication of the Cecil and Ida Green Building for Earth Sciences. On October 2, 1984, marking the exact date, Chairman David S. Saxon presided at a dinner at the M.I.T. Faculty Club, which included remarks by Mr. and Mrs. Green, former Department Heads of Earth, Atmospheric and Planetary Sciences, and President Paul M. Fye of the Woods Hole Oceanographic Institution. As part of this observance, on October 3 in Mc Dermott Hall, President Paul E. Gray introduced fellow Member, Frank Press, who delivered the Inaugural Lecture of a year-long series of afternoon talks sponsored by the Department. That event was followed by a symposium on October 4, honoring Dr. Press on his Sixtieth Birthday. Mr. and Mrs. Green also were co-hosts on October 3 with President and Mrs. Gray at the eleventh annual Ida M. Green Fellows Luncheon, honoring first-year women graduate student recipients of these prestigious fellowships.

The dedication on March 1, 1985 of the Albert and Vera List Visual Arts Center was the first of two celebrations marking the opening of the facilities in the Arts and Media Technology Building. Chairman Saxon presided at an afternoon speak program in Huntington Hall, Room 10-250, and later in the Atrium of the List Center. A reception followed. The relocation of the Hayden Gallery in these splendid new facilities designed by our former Member, I. M. Pei, and the tripling of gallery space available for the Institute's public art program have given the Committee on the Visual Arts
powerful new resources. The Corporation honored Mr. and Mrs. List and their family at
the Corporation Luncheon and the afternoon activities on March 1. The principal
dedication speaker was Marcia Tucker, Founder and Executive Director of The New Museum
of Contemporary Art of New York City.

The Arts and Media Technology Building, even in its partially completed state, served as
a powerful magnet to visitors to the campus and from the M.I.T. community itself. On
October 17, 1984, at the request of the International Council of the Museum of Modern
Art of New York City, which was holding its annual meeting in Boston, a special dinner
was organized for that distinguished group of international art patrons in the Building,
followed by dancing to the M.I.T. Intermission Band in the Atrium. The Institute is
deeply indebted to Jerilyn K. Edmondson, who volunteered her time to coordinate that
gala event.

At its meeting of June 3, 1985, the Corporation voted to name the Arts and Media
Technology Building in honor of Jerome B. Wiesner and Laya W. Wiesner in recognition of
their dedication to the Institute over more than four decades and their sustained
advocacy of the arts and communications technologies. Planning for the dedication of
the Wiesner Building is proceeding under a committee headed by Dean Jean P. de Monchaux
of the School of Architecture and Planning.

Dedication plaques were installed honoring the late Professor Joseph D. Everingham on
the thirtieth anniversary of the founding of Dramashop; Professor and Mrs. Nathan H.
Cook on the completion of their fifteen years as first Housemasters of MacGregor House;
Professor and Mrs. Robert I. Hulsizer on the completion of their eleven years as
Housemasters of Ashdown House; the Martin Foundation on the naming of the Martin Center
for Engineering Design in the Department of Mechanical Engineering; donors to the Center
for Real Estate Development; and donors to Project Athena. Each of these ceremonies
brought together students, faculty and friends in a spirit of renewal. In connection
with its December Meeting, the Corporation also sponsored an afternoon colloquium,
chaired by Provost Francis E. Low, in honor of faculty members who hold distinguished
appointments as Institute Professors and to named and endowed professorships. There
were countless additional departmental functions in which the Office of the Secretary
was called upon to advise in the planning process. These activities tend to peak in the
spring, but they were continuous throughout the year.

Once again, I wish to recognize the selfless dedication of Mary L. Morrissey, Director
of the Information Center, in the planning and creative execution of major facilities
dedications. She has been a joy and an indefatigable ally for the past ten years in
this frenetic work. Friends joined in June to celebrate her 35 years at the Institute.

Corporation Development Committee

Vice President Samuel A. Goldblith's talent and dedication are reflected in the report
of the staff organization to support the resource development activities of the
Institute. At the same time, no account of trusteeship can be complete without
recognizing the participation of individual Members of the Corporation in the Council on
Resources of the Institute, Corporation Development Committee, National Business
Committee, and Alumni Fund Board. In addition, many members of the Corporation have
headed or are serving as members of National Sponsoring Committees for professorship and
scholarship projects or departmental facilities. Three Members have assumed major roles
in planning the Institute's future capital needs--Carl M. Mueller, Joseph G. Gavin, Jr.,
and Breene M. Kerr. Our fellow Member, Yaichi Ayukawa, President, Techno-Venture
Company, Ltd., Tokyo, was named the 1984 recipient of the Marshall B. Dalton Award of
the Corporation Development Committee at its annual meeting "in recognition of
conspicuous and sustained service in the enhancing of M.I.T.'s financial independence."
Altogether, these leadership responsibilities and actions by the Corporation represent a
renewed sense of institutional purpose. They constitute a clear demonstration by the
Institute's governing body of its commitment to secure the necessary resources for
M.I.T.'s continued independence and strength in the years ahead.

It was the Institute's best gift year on record, and the third consecutive year in which
the grant total exceeded $50 million. Not included in these totals are severable million
dollars worth of equipment gifts, including computers donated as part of Project Athena,
and other vital equipment donations.
Meetings
As a matter of record, the Corporation held four meetings during the year. Chairman Saxon, President Gray, and Provost Low called upon all segments of the Institute community to continue the budget limitations needed to pull together in planning for a future balanced budget. In addition, through its various committees, the Corporation played a key role in communication with students, faculty, alumni, and the general public on the range of questions and issues before M.I.T.

Special thanks are due to the Ad Hoc Committee on Shareholder Responsibility, under the chairmanship of D. Reid Weedon, Jr., for its continuing assistance to the Executive Committee of the Corporation. Walter L. Milne, Assistant to the President and the Chairman of the Corporation, served again as Secretary to the Committee on Shareholder Responsibility. To use an expression by one of the former Chairman of the Corporation, he comes close to being the indispensable man.

Additional thanks are due the Corporation Screening Committee, under the Chairmanship of David R. Wilson and the staff of the Alumni Association for the effort required to conduct the special alumni election needed to fill a vacancy in the category of younger Member of the Corporation. Dr. Wilson has chaired the Screening Committee for the last four consecutive years. That process has set new standards of quality, and in doing so, it has brought Barbara M. Johnston, Heidi R. Wyle, Rhonda E. Peck, Arlene F. Roane, and Karen L. Fulbright into the Corporation. We are deeply in David Wilson's debt.

In notable actions, the Corporation held its Annual Meeting on October 5, 1984 as an all-day Meeting at Endicott House to discuss issues of long range importance to the Institute. On the preceding day, another innovation introduced by Chairman Saxon was an orientation meeting for incoming Corporation members. Both meetings were well received, and plans are underway to repeat them. At the March 1, 1985 Meeting, the Corporation approved the establishment of a new S.B. Degree in Mathematics with Computer Science in the School of Science to broaden the options open to undergraduates. A similar move was made in Physics, not requiring a formal change in the name of the Physics degree but allowing students to choose a Physics option jointly supervised by the Departments of Physics and Electrical Engineering and Computer Science. At the June 3, 1985 Meeting, the Corporation voted to amend the Bylaws so as to reduce the minimum age at which Life Members may request transfer to Life Member Emeritus from 70 to 65. The reduced age level is seen as an enabling factor when younger candidates are being considered for Life Membership.

At the June 3 Commencement Exercises, under sunny skies in Killian Court, Chairman Saxon welcomed Lee A. Iacocca, Chairman and Chief Executive Officer of Chrysler Corporation, the fourth outside invited speaker to address the graduating class in 21 years. The more than 1800 degrees awarded were personally handed to each recipient by the President. The Secretary continued the Institute tradition of hand-signing diplomas, bringing the total signed to more than 15,000 since John J. Wilson brought his total of 45,000 to a conclusion in 1979. In all, more than 105,000 M.I.T. degrees have been hand-signed since the founding of the Institute.

Corporation Visiting Committees
The 1984-85 year was a year of new activity for the Corporation Visiting Committees. Six meetings were held in the first semester and seven meetings were scheduled in the second semester. One Committee, for the Center for International Studies, was converted to an Advisory Board as a result of a reorganization of policy-oriented research centers at the Institute. Compared with 15 of the 28 Committees which met during 1983-84, the following total of 13 out of 27 Committees held meetings in 1984-85:

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<tr>
<th>Applied Biological Sciences</th>
<th>Materials Science &amp; Engineering</th>
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<td>Chemical Engineering</td>
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<td>Computer Science</td>
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<td>Sponsored Research</td>
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<td>Mathematics</td>
<td>Student Affairs</td>
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One of the above Committees met for two and one-half days, two met for two full days, and ten met for one and one-half days, for a cumulative total of 21 meeting days. Despite the drop in the number of Visiting Committees which met, the number of meeting days exceeded the previous year by 5 percent.

Under Chairman Saxon's leadership, the Corporation continued its in-depth study of Visiting Committee procedures. President Gray has observed that the obvious fact that the Corporation has been engaged and involved in these efforts to improve the effectiveness of Visiting Committees has reaffirmed the importance of the Committees and has had a noticeable effect on the quality of their performance. As one major improvement, oral reports are more timely and interesting. As part of this transition, a systematic, biannual evaluation of Visiting Committee performance with the President, Provost, and Secretary is continuing.

I want to recognize once again the exceptional performance of Mary S. Miller, Administrative Secretary in the Corporation Visiting Committee Office, in improving the planning and staffing of these meetings during the past four years. The resources of responsible, compassionate, sensitive, expert caring which she has brought to the management of Visiting Committee activity is one of the treasures of the Institute. She has cheerfully Shouldered the extra workload involved in longer meetings and more timely reporting. It has been a privilege to work with her.

The participation in this year's series of meetings by the senior officers and deans of the Institute continued at a high level. The presence of these officers at the various meetings enhances the interchange between the Committee and the Department and often provides a welcome catalytic effect which contributes to the success of the meeting. Enduring thanks are due Provost Low for his diligent participation in all of the meetings, and to the more than 300 faculty members who participated in the sessions of the Visiting Committees.

During his five years as Provost, Dr. Low participated in 76 Visiting Committee meetings. At the final Visiting Committee meeting of the year, with the Department of Chemical Engineering, Dr. Low was presented with an inscribed construction hard hat and, by acclaim of the faculty of that Department, was made an Honorary Chemical Engineer.

Of the Committees meeting in the 1983-84 and 1984-85 years, all of the meetings have now been reported orally to the Corporation save the last four. It was a year of playing "catch up" under our new system of reporting, and 19 oral reports were given. These reports to the Corporation are important to the successful operation of the Committees, and they provide a broadened forum in which to consider the plans and progress of each Department. They are invaluable to the functioning of trusteeship at M.I.T. The Academic Council systematically receives copies of the written reports when they are approved for distribution by the Executive Committee, and the Council also hears oral reports from the Provost and the responsible Dean or Vice President as Visiting Committee meetings occur.

An interesting development is continuing in the growth of "advisory boards" and committees affiliated with some of the major research laboratories and centers of the Institute. These Advisory Boards are not formally a part of the Corporation Visiting Committee system. They have been organized by the offices of the Vice President for Research and the various School Deans to serve the need of specific centers for an advisory body reporting to the Dean or the Vice President and providing advice to the research program director. At the same time, a number of Corporation members chair or serve on these Advisory Boards and have found them worthwhile and useful for the purposes intended. External Advisory Boards or committees have now been established for some 15 centers or laboratories. It is hoped that an annual compilation of these Boards can be made in the future to give greater recognition to the nearly 200 people serving as members, to encourage the increased appointment of women and minorities to these Boards and to provide another important avenue of participation in the affairs of the Institute by the Alumni Association. While many alumni participate on the Advisory Boards, there is reason to believe that the formalization of their participation as alumni could bring significant additional benefits.

The Office of the Secretary of the Institute has encouraged the directors of laboratories who have sought advice in establishing the various Advisory Boards. There is still some residual confusion between the functions of the Advisory Boards and the Corporation Visiting Committees, but I believe some progress has been made in distinguishing between the two. This aspect continues to be studied. The Membership
Committee of the Corporation has tried to take account of Corporation Member participation in these Advisory Boards in planning Visiting Committee assignments in recent years. A partial listing of the current Advisory Boards follows:

- Center for International Studies
- Plasma Fusion Center
- Energy Policy Research Center
- Systems Dynamics Group
- Joint Center for Housing Studies
- Center for Advanced Engineering Study
- Center for Transportation Studies
- Energy Laboratory
- Center for Materials Processing
- Center for Technology, Policy, and Industrial Development
- Sea Grant Program
- Laboratory for Manufacturing and Productivity

Acknowledgments

I wish to thank Dorothy G. Adler of the M.I.T. Alumni Association for her continued support of the nomination of alumni to the Visiting Committees and for the assistance to the Corporation Screening Committee for younger alumni. Elizabeth J. Whitaker, Assistant Secretary of the Corporation, continued her monumental contribution to the Institute in quiet ways. I have come to rely upon her good judgment and taste in planning the affairs of the Corporation. I am personally indebted to Elizabeth A. Gerber for her ability to innovate and absorb sustained workload cheerfully and efficiently. She made possible the smooth handling of the quarterly Meetings of the Corporation and related events during the year. Her generous spirit has been a lesson in the degree to which organizational effectiveness depends on the dedication of individuals.

Priscilla K. Gray once again heads the list of M.I.T. volunteers for the quality and character of her sustained contributions. She exemplifies an army of talented spouses of M.I.T. staff and employees who contribute every day to the Institute's mission. It is altogether too easy to take this group of selfless volunteers for granted in analyzing the strength of the Institute. What the Institute has always lacked in financial resources, it has made do with extra commitment from members of the M.I.T. community. The Institute's deepest pockets have always been in its volunteers, paid and unpaid alike. Its spouses deserve more recognition than we can possibly give them.

This year has been punctuated with so many truly outstanding events and accomplishments that it is difficult to single out any one of them. For the writer, the publication of James R. Killian, Jr.'s autobiography by the M.I.T. Press, entitled The Education of a College President, has had particular meaning. The spirit of renewal which is in Dr. Killian's book brings home time and time again M.I.T.'s extraordinary good fortune in his zealous devotion and the Institute's ability to move gracefully from one period to the next under new leaders, seemingly without missing a beat in its corporate and academic life. The book ought to be required reading for all men and women of M.I.T. It ought to be recommended reading for decision makers everywhere.

I welcome this opportunity to salute Dr. Killian on the occasion of my own retirement. Twenty-five years ago he invited me to join his office as Executive Assistant, from an earlier series of assignments in the Industrial Liaison Office. He and President Stratton subsequently named me Vice President and Secretary of the Institute in 1963. What I learned from them and their successors—Howard W. Johnson, Jerome B. Wiesner, Paul E. Gray, and David S. Saxon—can best be described as the education of a university secretary—100 Corporation Meetings and over 400 Corporation Visiting Committee meetings later.

VINCENT A. FULMER
Alumni Association

Records exist to be broken but 1984-85 will always stand as a year of three milestones. First, following an unbroken line of 89 male presidents the Alumni Association was most ably led by Mary Frances Wagley '47. Second, the Alumni Fund achieved a record-breaking cash flow of $10,128.00. Third, at a joint meeting of the Board of Directors and the Fund Board, President Paul E. Gray '54, and Chairman David S. Saxon '41, spoke about the Institute's exceptional strength and its under-capitalization. A major capital fund drive is being planned to meet this need. The Association has been asked to play a major role and it has responded with an enthusiastic yes.

Other achievements of special note need to be mentioned. The first of a new style Alumni Register was delivered. Alumni programs, such as the Enterprise Forum, continue to grow at an exceptional rate. Finally, Technology Review won national recognition from the Magazine Publishers Association as one of six finalists in the National Magazine award in the field of public service. These results are due wholly to the efforts of outstanding people, volunteers and staff alike. The Alumni Association has benefitted from enlightened, energetic, committed and thoughtful volunteer alumni leadership coupled with an equally vigorous, hard-working and remarkable staff. This mixture of first-rate people, dedicated to the support of MIT, their fellow alumni and each other will continue to enrich, enliven and stimulate MIT.

Mary Frances Wagley, Class of 1947, the 90th President of the Alumni Association, served with energy, commitment, wisdom, and added a very special grace to the office. She developed, with the able support of Shirley Picardi '72, Secretary of the Association, a first-rate slide tape presentation entitled, "Women at MIT: Past, Present and Future." She delivered that talk to 17 clubs and spoke to nine other alumni organizations. Peter Saint Germain, Class of 1948, served as Chairman of the Alumni Fund Board and Robert W. Mann, Class of 1950, Whitaker Professor of Biomedical Engineering, ably assumed the role of Chairman of the National Selection Committee. A special note of thanks goes to the Board of Directors of the Association who serve MIT so well. These volunteer leaders exemplify the work of thousands of dedicated people who serve MIT.

The Secretary of the Alumni Association, Shirley M. Picardi '72, resigned this year to become Bursar at MIT. We have profited immensely from her energy, commitment and hard work. Her mark on the Association is a valued and lasting one.

Alumni Relations

The National Alumni Conference was held in two locations this past year, Toronto on September 21 and 22, and Dallas on October 12 and 13. These meetings of NAC "on the road" were aimed at helping alumni in all of their volunteer roles. Our outreach to other cities has proved of value but audiences in both locations were considerably short of expectations. President Paul E. Gray '54, and his wife Priscilla, honorary alumna, graced us with their presence in both cities. In Toronto a distinguished panel of MIT economists led by Dean Ann F. Friedlaender, EC '64, and including Professor Paul R. Krugman, EC '77, Professor Olivier Jean Blanchard, EC '77, and Professor James M. Poterba discussed international economics. Professor James M. Ham, EE '47, former President of the University of Toronto delivered the Richards Lecture. In Dallas a panel of alumni, faculty, and administrators discussed entrepreneurship in its many and varied ongoing connections with MIT. William J. Hecht '61, Executive Vice President of the Alumni Association chaired the panel including Dr. David G. Jansson '68, Director of the MIT Innovative Center, Dr. Allan S. Buffere '59, Associate Treasurer and Recording Secretary of the Institute and Russell N. Cox '49, a private investor and a founder of the MIT Enterprise Forum.

The Alumni Council series continued on its successful path. One largely student presentation concerning the Monarch, a record-breaking man-powered airplane drew an outstanding response. The Cardinal and Gray Society and the Boston Seminar Series again had successful years.

Student/alumni programs grew in their varied and diverse routes. Changes adopted by the Undergraduate Association will lead to clearer student leadership during the senior year. Programs involving seniors center on our hugely successful Senior Dinners which continue to be held at the Presidents House through the enthusiastic and active participation of Dr. and Mrs. Gray. Many clubs work with the Educational Council in their local regions to sponsor meetings of applicants and students during the various stages of the application process.

The Black Alumni of MIT (BAMIT) sponsored the twelfth "MIT Black Student Conference on Science and Technology" on October 13 and 14, 1984. In conjunction with that event BAMIT held its annual alumni meeting.

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The Association of MIT Alumnae (AMITA), in conjunction with the Boston section of the Society of Women Engineers sponsored their fifth annual conference, "Beyond Entry Level: The Maturing of Women's Technical Careers" on March 15 and 16, 1985. Attendance was approximately 300. AMITA continued its highly successful volunteer-run high school visiting program. For the ninth year the IAP program, "Getting the Job You Want in Industry: A Woman's Guide to the Pinstriped World" was run successfully.

The Enterprise ForumSM continues its growth. This academic year it has grown to include nine cities in the United States and one in Mexico. The various local forums, including two joint ventures, one with the California Institute of Technology and one with The University of Miami, continue to thrive in their format of live business cases presented to a panel and participating audience. Workshops in Cambridge focused on "Excellence in Entrepreneurship: Building a Quality Company" and in Washington, focusing in that same area, drew audiences approaching 1000. One of the Forum founders has published a book entitled, Business Plans That Win $$$: Lessons From the MIT Enterprise Forum SM which has been used by the Harvard Business School.

Technology Day, June 7, 1985 focused on the topic "Fundamental Work in the Life Sciences." Four faculty members Professors Malcolm L. Geftter, Ann M. Graybiel, PS '71, David E. Housman and, Robert A. Weinberg, LI '64, moderated by Professor Gene M. Brown, Dean of Science-designate and Head of the Department of Biology entranced an audience with the wonder, richness and complexity of modern biology. Over 1200 people participated in the symposium and T-Day luncheon program. "Tech Night at the Pops" was, as always, a festive sellout.

As always regional activity remained a backbone of volunteer work. Well over 500 events were scheduled in over 70 clubs world-wide. The Association President, Mary Frances Wagley '47, travelled extensively to a wide number of areas including a visit to the MIT Club of Taiwan. The active thoughtful efforts of volunteers and the Association staff in the regional area deserve immense credit for the ongoing activity.

The Committee on Alumni Nominations for Corporation Visiting Committees recommended to the Corporation that 27 members whose terms had expired be ended, that 30 terms be extended, and that 30 new alumni members be appointed to visiting committees.

The Board of Directors appointed 26 new alumni members and seven chairmen to serve on the seven national boards and committees of the Association. The Board also approved the following recommendations of the Awards Committee:

Bronze Beaver Awards: Margaret T. Coleman, Class of 1950; Raymond H. Danon, Class of 1958; Louis E. Stahl, Class of 1936; Carl Henry Wilson, Class of 1934.

The Harold E. Lobdell, Class of 1917, Distinguished Service Awards: Barry R. Bronfin, Class of 1960; Karnig Dinjian, Class of 1929; Priscilla K. Gray (H); John W. Jenkins, Class of 1943, Bonny Kellermann, Class of 1972; Karen Nathiasen, Class of 1971; Edward B. McLaughlin, Class of 1925; Philip M. Richardson, Class of 1959; Lindsay Russell, Class of 1950; R. Gary Schweikhardt, Class of 1974.

The George B. Morgan, Class of 1920, Awards: Kevin Campbell, Class of 1976; Leslie Cline, Class of 1949; Wallace Couch, Class of 1962; Arthur Josephs, Class of 1928G; Harold Spaans, Class of 1930; David Weiss, Class of 1952.

Presidential Citations: Boston Stein Club; MIT Club of New Jersey; MIT Enterprise Forum-IAP Program; Washington DC Seminar Series; Class of 1974.

Honorary Membership in the Alumni Association: Joyce E. Brado, John A. Tucker.

The following alumni were elected by national ballot to serve three year terms on the National Selection Committee: Harl P. Aldrich, Jr., Class of 1947, District #1; Joseph E. Dietzgen, Class of 1941, District #2; Ronald E. Enstrom, Class of 1957, District #4.


The National Selection Committee made the following selections for terms starting July 1, 1985:

Terms on the Corporation: Michael M. Koerner, Class of 1949; Christian J. Matthew, Class of 1943; Robert Swanson, Class of 1969 (all five year terms). President of the Alumni Association: E. Milton Bevington, Class of 1949 (one year term). Vice Presidents of the Association: Richard A. Jacobs, Class of 1956; Emily V. Wade, Class of 1945 (two year terms). Director of the Association: William Hosley, Class of 1948, District #3; Vito A. Caravito, Class of 1962, District #6; Viguen Ter-Minassian, Class of 1964, District #7; Bill C. Booziotis, Class of AR '60; District #8, Robert Muh, Class of 1959, District #9 (two year terms).
In the Alumni Relations area, Raju Patel, GM '77 and Lawrence A. Milan, Regional Directors for New England and the Midwest respectively, resigned. They were replaced by Webb F. Elkins, SL '83 for the Midwest and Janet L. Serman for New England.

Alumni Fund

Continuing its record of accomplishments, the Alumni Fund, chaired by Peter M. Saint Germain, Class of 1948, reported a total of $10,128,000 in contributions from 27,529 alumni. This remarkable testament to alumni support of the Institute represents the eleventh consecutive year of dollar increases. Further, it marks the sixth year in the last seven that total dollars contributed to the Alumni Fund represented a new million dollar giving plateau, in this case, an eight digit sum.

In addition to the record dollar total, 1985 represented the end point of a five-year plan established in 1980 to broaden the base of alumni support and to seek substantial levels of upgraded giving. Overall, the Fund has exceeded its long-term objective of an annual net growth in participation of 500 contributors and achievement of 30 percent of the gifts at the $100 or greater level. Measured against a base year of 1980, the net annual growth of participation in the Fund has averaged nearly 800, while this year's total of 8,500 contributors at the $100 or greater level represents 31 percent of the total alumni participants. Other impressive totals this year are the 3,200 alumni, representing 12 percent of the contributors who gave a gift of $250 or more and the 1,800 alumni who made their first contribution to the Alumni Fund.

Graduate alumni achieved an impressive rate of 49 percent participation in the Fund while graduate alumni matched last year's 33 percent participation level.

Fund solicitation programs, including Direct Mail, Major Reunion Gift, Matching Gift, Senior Gift, Telethon, and Young Alumni, were conducted in the established format. The Graduate Alumni Program, aimed at individuals with a graduate degree from MIT, completed its second successful year of departmental fund raising as well.

Regional solicitation programs were conducted throughout the United States. Fall telethons were held in six cities, and the Personal Solicitation Program was hosted in four. This year's Personal Solicitation Program (P.S.) included a special effort in San Francisco and New York City, which focused on seeking increased giving at the $500-$5,000 range. Overall, 50 volunteers made personal appeals to some 250 individuals, seeking upgraded gifts to the Alumni Fund. Of those alumni who pledged, 59 percent increased their level of support for MIT, thus meeting the objectives of this key solicitation program. Due to staff shortages within the Alumni Association, fall regional program results were slightly behind the FY85 targets, but due to the effort of existing staff to increase the number of spring telethons, the final results met overall Fund objectives.

Telethons continue to be the primary method of securing increased levels of support from regular contributors and adding new donors to the Fund. Overall, 1,004 volunteers, both student and alumni, contacted almost 17,000 individuals by phone. A total of 11,605 pledges in the amount of $706,000 was raised in this effort, an 8 percent increase in dollars over 1984.

Support of the Fund by its young alumni continues to grow. To wit, a total of 661 alumni from the five most recently graduated classes made a first time gift to the Fund this year, and the 10th and 5th reunion programs remain strong. The Class of 1975 raised $31,000 toward a Student Aid Fund, and nearly $40,000 overall for its 10th Reunion Gift. The Class of 1980 followed this trend by contributing over $25,000 toward the endowment of a student aid fund as well.

Major reunion gifts of more than $8.8 million were announced on Technology Day 1985. Included in the totals were gifts in the prior five years and pledges projected through 1990. The 50th Reunion Class of 1935 announced a total gift of $3,740,000, the second largest reunion gift in MIT's history. The Class of 1935 further distinguished itself by earning a heretofore unrivaled figure of 97% participation. The Class of 1945, celebrating its 40th Reunion, announced a gift of $1,125,000, raised from 65% of its class members.

The Class of 1960 presented a 25th Reunion Gift of $1,960,000, the largest 25th Reunion Gift in MIT's history. $346,000 of the gift will be used to establish an Endowment for Innovation in Education that will fund new undergraduate and graduate educational programs. 67% of the class participated in this effort.

Reunion gift presentations also included a 60th Reunion Gift from the Class of 1925 in the amount of $1,910,000.

Of special note in Fund Year 1985 was the establishment of a new program of donor recognition entitled, the "President's Fund." In order to promote support of MIT's core needs--student financial aid, unrestricted, endowment of professorships--the Alumni Fund Board established this new recognition program for annual donors at the $1,000 level or more. In this first year, more than 800 alumni met the eligibility criteria of the President's Fund.
Finally, Fund Year 1985 has been marked by considerable changes in staff. Gloria A. Westover was promoted to Manager of Internal Programs, and Jeffrey R. Solof, Class of 1981, rejoined the Fund as Assistant to the Director. Nancie M. Barber was appointed Assistant Director, while Janet L. Serman transferred within the Alumni Association giving up her post as Director, Graduate Alumni Programs to become New England Regional Director. Neil W. Didriksen left the Fund staff to accept a position as the Director of Leadership Gifts in MIT's Office of Resource Development. The accomplishments of this record-breaking year reflect well on the efforts of thousands of committed volunteer alumni supported in outstanding fashion by the Alumni Fund staff.

TECHNOLOGY REVIEW

Technology Review ended 1984-85 by winning the Sibley Award for the "magazine of the year" from the Council for the Advancement and Support of Education. This continued our winning ways since this was our second Sibley in a row. Our highest kudos for the year came in the form of a nomination for a National Magazine Award in the field of public service for our publication of "The Not-So-Clean Business of Making Chips" by Professor Joseph LaDou of the University of California at San Francisco (May/June 1984). Though the final award went to another nominee (of six), the Review's honor is not to be denied; we believe it may be the first such nomination ever made of an alumni-published magazine. Another major award brought a silver medal from the Art Directors Club of New York for artist Rob Colvin's frontspiece illustration for an article on antisatellite weapons (August/September, 1984), and four Technology Review entries were accepted for publication in Print magazine's 1983 Regional Design Annual.

The Review continued its editorial emphasis on the implications of technological change, an arena in which there is little direct editorial competition except that provided by the quarterly founded by the National Academies of Sciences and Engineering--Issues in Science and Technology, the style of which is very different from ours. At the risk of underestimating the value of many other contributions, it is possible to list a few editorial highlights of 1984-85:
- "The Politics of Starvation" by Nevin S. Scrimshaw (August/September), a proposal that political rather than technical change is needed to end food shortages in many developing countries.
- "Too Little Aid for AIDS" by Judith Randal (August/September), which previewed a topic that came into general public discussion early in 1985.
- The Fourth Transformation in Autos" by James Womack and Daniel Jones (October), an article-length summary of the major findings of the MIT International Automobile Program.
- "Women in Technology" (November/December), a special section exploring the unrealized role of women in engineering and its causes.
- "The Automated Factory" (January), two articles on the technical status and human implications of the increasing use of robots.
- "Conversing with Computers" by Richard A. Bolt (February/March), how computers can be made to capture the richness of human communication.
- "Recycled Weapons" by Gerald M. Steinberg, an account of Israel's success in upgrading obsolete and damaged weapons.
- "Oppenheimer and the Radioactive-Poison Plan" by Barton J. Bernstein, a footnote to history that captured the imagination of the press upon its publication in our May/June issue.
- "Helping Paraplegics Walk" by Howard J. Chizeck (July), an account of how electrical impulses can be used to restore function in paralyzed muscles--and the many obstacles that remain to be solved before this new technology can be a practical aid for many victims of spinal-cord accidents.

Frequent references to our content in other media and a continuing flow or reprint requests have been reassuring measures of editorial success during the year.

Much of the Review's editorial content is now being condensed and translated for publication in Beruf, a Tokyo-based Japanese-language magazine devoted to new developments, especially in the personnel field, in Japan.

The coverage of MIT affairs in our "A" pages has been markedly improved this year under the management of Susan Lewis, Senior Editor. Notable have been major reports on rushing by Donald M. Davidoff (November/December), the fifteenth anniversary of UROP by Susan Lewis (November/December), the 100th anniversary of music at MIT by China Altman (April) and Professor John Deutch '61, Provost-elect by Susan Lewis (July). The continuing columns on MIT affairs by Diana ben-Aaron '85 represent an outstanding series by an undergraduate--perhaps the best we have had in my experience as Editor.
The Review's circulation has stabilized this year, with print orders in the range of 70,000 copies of each issue. Of these, 35,000 have been required for alumni distribution, with the balance supplied to "paid" and "trial offer" subscribers. Renewal rates have remained constant, and there has been a very small increase in the rate of our acceptance by "trial offer" subscribers that results in a slight decrease in the cost of acquiring new subscriptions. Both factors are in fact encouraging in a year when science- and technology-based magazines have been experiencing market problems.

But perhaps the most encouraging development has been the increasing acceptance of the Review by advertisers. New records for advertising revenue have been set in several issues, thanks chiefly to the successful efforts of The Leadership Network. Peter Gellatly, Business Manager of the Review, has become the Chairman of the Network's publisher group, and he has also organized independent representation of the Review in the Greater Boston "high-technology" community.

The Review was fortunate in 1984-85 to gain the acceptance of Edward T. Thompson '49, former Editor-in-Chief of Readers Digest, to be Chairman of its Editorial Advisory Board. He has taken an active role in the Review's affairs this year, and we have come to cherish his support in the same way we had previously relied on Claude W. Brenner '47, Thompson's long-time predecessor in this vital role. In addition, we have gained the support of Louis Menand, Special Assistant to the Provost, and Professor Lester D. Thurow of the Sloan School of Management as members of the Board. The death of Professor J. Herbert Hollomon '40 of Boston University late in the year deprived us of the wisdom and enthusiasm that he had brought to the Board over a period of at least 15 years.

RECORDS/ADMINISTRATION

Delivery of the 1984 ALUMNI REGISTER was made from the printing plant in Indiana in November 1984. Since then we have carried out the invoicing and payment collection for the 50% of the books which were ordered on the bill at shipment option.

During the year we have worked with the Administrative Systems development team and members of the Alumni Relations staff on the development of the Activities File on the database. This file is intended to preserve historical records of alumni participation in various Alumni Relations programs. Further work was done with this group to clarify geographic coding in the Zip File and to implement the use of the Club File to record alumni membership in various club organizations.

A major project was undertaken with members of the Alumni Fund staff to develop a new file to support the information needs of the Reunion Gift program. We expect both new files to be in operation for the beginning of fiscal 1986.

Initial planning has been accomplished to replace the terminal network to the mainframe and to complete outstanding development on the database in anticipation of increasing demands on the information system in preparation for the MIT Campaign.

The database now contains 107,919 records, 87,189 alumni and 20,730 records for all other donors to the Institute and provides interactive on-line information resources for the Treasurer's Office, Resource Development, and the Sloan School, as well as for the Alumni Association. Other administrative offices such as the Admissions, the Bursar, and the MIT Accounting Office also use the database for reference, and we provide specialized programs for their access to the information required.

We have continued to provide training and programming support for the expanding number of users of the Alumni/Gift database in the MIT community.

A search to fill the position of Associate Director of Information Management was initiated but the position has not yet been filled.

A decision to separate the dual responsibility of the Director of Information Management for administrative functions of the department and management of the information systems was approved by the Board of Directors at their March meeting. An Administrative Officer position was defined to supersede the position of Manager of Administrative Operations currently filled by Kathy Pinklestein, who has resigned. She will remain until the search to fill the Administrative Officer position is completed. The administrative operation of the department has continued without major change during fiscal 1985.

WILLIAM J. HECHT