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I

No one can say that the year just past was a dull one. As the annual reports of our schools and departments bear out, 1967-68 was a lively year at M.I.T. It has also been one of proud achievement, as measured by all the ordinary standards.

But the year just past was not an ordinary year. Major symptoms of changing views, strong reactions, and growing concerns have shown up in nearly every aspect of our society. That this ferment should be felt especially on the college campuses across the country, and across the world is not surprising. It may be interesting to speculate why such massive changes in the ordering of relationships should occur once or twice in a century. It is vital that we all recognize that they are occurring now. All institutions in times like these are bound to have difficulty in responding wisely to new questions and new pressures. Nevertheless the universities, the proving ground of our youth, are expected to respond with understanding, with creative imagination, and with a strong sense of responsibility toward their own constituents — students, faculty, and alumni — and toward society as a whole.

Some of the more vocal of the country’s critics would have us believe that no human endeavor is so firmly anchored to the past as higher education. The charge may be more rooted in feelings than in analysis; but the feelings are strong and are more widely held than many believe. In any case, all of us in the colleges and universities must strive to understand the dynamics of our times as we seek a navigable passage to the future. And it seems especially fitting that M.I.T., which has long been engaged in continuous change, should help to find the way in times such as these.
In my last report I sought to list the priorities that sustain intellectual effort at the Institute. The measure of our progress in these fields is properly reported in the separate accounts of the schools and centers. I hope the reader will be conscious, as I am, of the many places in which the evidence accumulates — of our interest and accomplishment and, perhaps more important, our new expectations in these fields.

As part of my report this year, I want to examine both the basis and the direction of the changes that we have experienced in the past as well as those that are molding the future.

The problems that bedevil society today, that tear at its heart, and that reflect and magnify themselves on the campuses, relate to the basic arrangements for living in a modern world. It is necessary but insufficient thinking, I believe, to relate them wholly to crises in the international situation — the war — or to crises in the domestic situation — what has been aptly called the white problem. Transcendent as these crises are, there is at least hope, and in my judgment the expectation, that reason will prevail in ending the war, and that effective progress will finally be made in ending the deep schisms and the disparity of opportunity that exist between the races.

There are, however, even more basic dilemmas that plague our sense of well-being, our belief in ourselves, and our ability to cope with the new forms of crisis that will emerge in every year of every man's life. And these dilemmas go to the heart of the uneasiness and the sense of outrage that we see on the campuses all over the world. I would state some of these dilemmas as follows:

On the one hand, we know that these are times when the most basic problems of our living arrangements can be solved only by the application of large technical systems; while, on the other hand, we feel a deep yearning for individual participation and expression and for the small-scale, person-sized contribution.

On one hand, there is an obvious need for interdependence and close communication among people, organizations, cities and nations. Yet, on the other hand, there is a profound wish for independence and privacy on the part of individuals and groups in all human institutions.

Over the years, subtle checks and balances in our political and economic life have developed into complex controls, whose operations have become automatic and self-generating. Many of our youth today resist these “systems,” in ways that often appear to be self-centered flights for personal freedom and individuality. There is an inexorable tendency toward centralization at a time when many seek decentralization in decision and action and responsibility. Paradoxically, large concentrations of
power in nations and organizations seem curiously powerless and vulnerable in their dealings with strong-willed minorities in their constituencies.

Coupled with these dilemmas between massive interrelations, from which there can be no escape, and the need for individuality, there is still another problem related to the effectiveness of large-scale technological effort. This is a deep criticism that what has produced and continues to produce so well for so many people has produced so little for a sizeable group in this country or for an even larger group in the world as a whole.

There is, finally, a gnawing doubt expressed by those who question whether a large-scale technically based economy such as ours could function well without the goad of war, and whether peace can generate the demand necessary to sustain a healthy society.

In some ways, all of these dilemmas, which disturb people in every walk of life, seem especially violent in their philosophical impact on the campus. They lead us to ask, once again, whether we need a moral equivalent of war in our society; whether a singular objective, and a process in which every person has a part—a process that produces a commonweal that motivates each man to do his best—is, in fact, the prime priority of a crowded world.

We do not know if these paradoxes can be resolved, but I am hopeful that we are making progress toward their solution. I see the new awareness on the campus among students and faculty, again reflecting the whole American society, as a cause for optimism. The awakened interest in the answer to age-old problems of inequity among men; the renewed concern about the quality of life—these, if directed into positive action, could finally create the moral equivalents that man has long been seeking. It seems to me that the new ethos of concern for one’s fellow men is the first necessary step.

This first step is especially significant in a science-based university; for I strongly believe that, if we are to succeed in factoring the dilemmas of today’s world, science and its applications—modern engineering, if you will—must be more powerfully involved, not less so. I believe, too, that within the science-based learning environment, we can develop a more effective laboratory for leadership than has so far been possible. This combination of increased involvement and opportunity—by the Faculty and the students of the Institute—emphasizes for me the meaning of an education in the broadest liberal and scientific sense; an education in which learning with a purpose and a professional approach is accompanied by an abiding concern for the condition of man.
I find, therefore, in the revitalized efforts of our academic community to understand, to seek a deeper and more meaningful education and to propose new approaches, a positive and hopeful evidence of new ground gained.

It hardly seems necessary to add that in the searchings of our students and Faculty, we welcome new approaches, barring only those which tend to degrade members of the community, or that damage in irreparable ways the delicate fabric of the university. But I, for one, continue to expect no such distortions at M.I.T.

II

Let me now turn to those ways that make sense in encouraging the thoughtful responses of our community to what I have described as the vexing dilemmas of our time. I believe that it is in these responses of the M.I.T. students that we shall find the real meaning of an M.I.T. education for the present and for the future. To put it simply: M.I.T. is, and should continue to be, a student-centered institution of learning.

We expect the student here to work extremely hard at his own education. We want him to pursue his studies in a mature manner and in his own personal style. We seek an ever higher standard by which to measure his performance as a potential contributor to a better society. We ask a lot of him. In return, we must be prepared to give him a wide opportunity to formulate his plans, to have full access to the resources of M.I.T., and to write his own educational ticket, to the extent that this makes sense. I believe, therefore, that our goals in the classroom, in the laboratory, and in the decision-making process of the Institute should be to increase the latitude of choice and to broaden those opportunities through which the students develop, improve, and individualize the basic learning environment.

Ours must remain a community where, above all, learning is the outcome of experience. It is important, too, that we extend this climate to all in our community, to include faculty, staff, and employees, as well as students. I believe that an attitude of adaptability and a continuing, persistent, and pressing concern for student involvement in the affairs of M.I.T. will foster this learning climate.

I would sooner see the Institute err in overachievement in these matters than in underachievement.

A second way we can make sure that the Institute holds its rightful place in resolving the dilemmas of our time is by pressing for a concerted attack on those problems that bridge across more than one field and deal
with the human purpose. I have in mind here the areas of urban affairs, international development, public policy, the interrelationship of medicine, engineering, and science, and indeed, the issue of more effective learning itself.

Last year we made significant advances toward a new level of performance in urban affairs. We have new professorships, an interdepartmental laboratory, and a score of major studies and programs under way. Our Faculty is involved in more than 200 projects related to the urban field. Quite appropriately, our focus is the harnessing of modern technology to meet the human needs of the city. I believe that we will succeed; but I am less sure than I was last year at this time that an adequate scale of effort can be mounted within our present structure of disciplines, departments, and centers. In the urban, as in other interdepartmental and interschool fields, the Institute must seek new ways to enable academic work to flourish in close cooperation with practice.

As we look for a better organization of our urban effort, I see us inventing ways that will be useful in other areas and to other institutions. It is wholly within our tradition to innovate in method as well as in substance and, once again, we are called to the test.

I turn, thirdly, to the concerns of the Faculty, the bone structure of the Institute. Here is the core of the quality of M.I.T. — its continuity, its willingness to stay young, its reach to the future. In these times of intellectual and moral ferment, the Faculty is eager to press forward, to experiment, to dedicate itself. I believe that we shall continue to see strong advances in the fields in which M.I.T. has prominence and reputation second to none. Whether in science and engineering, in architecture and the humanities, or in management and the social sciences, M.I.T. men work at the frontier of discovery and their purpose is always to extend the horizon of knowledge. That, I suppose, is now regarded as commonplace; it is to be expected and is reported fully in the reports of the deans. We expect it, but we dare not take it for granted; for the impact of our type of education continues to set the standard, and guarantees that we shall attract to our community many of the most brilliant minds and the most creative talents.

In reviewing the past year, I should especially like to note two types of concerns that occupy a major portion of faculty thinking. The first relates to teaching, and more broadly to the shaping and reshaping of the content of our curriculum, and to the improvement of its methods of presentation. Under the aegis of a competent and especially energetic Committee on Educational Policy, the Faculty is currently reviewing a range of issues, from admissions policy and reform of the undergraduate
core requirements, to alternative means of evaluating student performance, to new experiments in counseling and the advisory system, and to what may be called an inventive "classroom technology" that would utilize our modern computation and communication techniques.

Last year saw major new impetus in all these areas. A great measure of energy and resources will be channeled into these efforts this year, and our expectations are high. There may well have been a flight from teaching in the American academic community, but it seems to me that the trend is now clearly changing. Perhaps, before too long, there will be concern that the professor is not research-oriented enough. The two primary efforts of the professor — teaching and research — require a balance that is both dynamic and demanding. The balance at M.I.T. is in a good state.

A second area of faculty concern has been one of compelling interest on the part of many in our society. It is the concern for much-needed improvement of the opportunities for the Negro; in our case, for educational opportunities in science and engineering especially, and for participation by members of the black community in all of the programs available for study at M.I.T. These concerns reflect a sense of urgency and priority that virtually all of the members of our community share. Our purpose is both to admit more individuals from a disadvantaged background to our regular M.I.T. programs and to create special studies and opportunities for those previously overlooked.

Largely on the initiatives of individual members of the Institute community, new ideas have been developed relating to the use of M.I.T. resources to aid in the education of our disadvantaged neighbors. The long record of these programs, projects, plans and proposals cannot be included here, but I have briefly described a sampling of them in a recent report to our alumni officers. Clearly, one of our tasks now is to look carefully at the range of opportunities before us, and to respond with wider institutional commitment of time and resources to those which best meet the test of public service and learning.

III

I have said here that the crises of our times, as reflected on our campuses, should be seen as timely opportunities to make substantial progress on the solution of age-old problems. I have said that, in my judgment, we at M.I.T. will be better prepared to take the wind now coming up if we make sure that we give our students all the opportunity they seek and all the responsibility they can carry. We must open the
way for constructive effort by demonstrating our willingness to assign resources as well as attention to the larger problems of society that we have never adequately attacked before. Finally, we should remember that at M.I.T. the essential way of advancement of the Institute lies in the interests, the expectations, and the performance of its Faculty.

IV

In its efforts to deal constructively with the urgencies that mark the times, the Institute has turned often to self-studies that have formed the base for charting more effective new directions as well as for changing existing structure. In some situations, these analytical and philosophical investigations were formalized in large-scale efforts. Two decades ago, the Report of the Committee on Educational Survey, under the leadership of Professor Warren K. Lewis, gave foundation for a whole generation of effort and expansion in the humanities; and in the early 1960's, the Report of the Committee on Curriculum Content Planning, under Professor Jerrold R. Zacharias, set new goals for the structure of the undergraduate years. For the most part, however, such investigations have centered on questions of curriculum. In the past year, we have pursued these patterns of self-study in several areas, and I find them wholly constructive in their result. I hope we can continue these studies, large and small in scale, with the help and participation of everyone at the Institute, including members of the Corporation, the Faculty, and the student body. An attitude of self-improvement and a willingness to recognize weaknesses can open the door to real advance.

Last year, as one aspect of introspection, we began a more systematic attack on questions of management information gathering, administrative decision models, and a more cohesive approach to the institutional planning process. Aided by a newly created office of organization systems, we expect to sharpen our practices of internal studies, evaluations, and staff consulting for administrative operations. We are already tapping the resources of expertise in our own Faculty and we look forward to the kind of improved efficiency that will permit us to do a more effective job at the servicing and the direction of our academic goals.

In the conduct of reviews, self-studies and evaluations, and generally in the whole process of improvement of the educational process and of the opportunities for participation in it, the university makes use of the experimental approach. Robert Louis Stevenson once said that youth is wholly experimental. In a science-based university, this is especially so, and understanding this process goes a long way to explaining the nature of M.I.T.
People outside the university must comprehend and accept this fact. And the members of the academic community must always recognize that implicit in such a franchise and such a license given to us by the wider society is the expectation that we proceed responsibly to invent the future.

I should like to diverge here from the pattern of this report to include a brief comment on two special problems which threaten to hurt the Institute and, more broadly, the educational scene and the national efforts for the continued maintenance of the standards of excellence in our universities.

As everyone knows, 1968 and 1969 are fiscal years marked by large and aggressive cuts in Federal financial support for research, especially in science and engineering. The year 1970 looks no better and could, in fact, be worse. These cuts now begin to affect our activities in a serious way, and it is my duty to warn of the dangers that will surely result if the country does not act promptly to reorder priorities.

In critical fields of the Institute's concerns, we see before us sizeable reductions in levels of support for research. I would not say that all cuts are inappropriate or unhealthy. Sometimes they force a necessary pruning, as long as strong and new growth is encouraged. But indiscriminate and general reductions have the net effect of lessening forward momentum in science and engineering and damaging seriously the education of scientists and engineers in this country. In the long run, if continued, the price of the slowdown in support will have serious effects at M.I.T., and, over a period of time, will have serious effects on the progress of this nation.

Part of the blame for this deeply worrisome situation must be laid at the doors of the universities themselves. Over the years, we have been either not interested or not effective enough in persuading the country that forward progress depends on ideas, and ideas depend on people and the facilities to test them. This is a task we must take on without delay.

In a larger frame, the necessity of support, both governmentally and privately based, seems even more urgent, if the country's great resources of education are to proceed at reasonable speed. We have had a good year, judged by the way that our private sources of support — individuals, corporations, and foundations — have responded to our needs. Without that support, the outlook would be bleak indeed. The Federal sources, understandably, but no less significantly in terms of the consequences, have not been responsive to our needs. There is much to be concerned
about, and much to be done. But I see no quick solutions or quick returns to a wiser course.

A different kind of problem related to the national purpose and effort is the draft problem. I have commented on this in other contexts. I simply repeat here that what concerns us most is the effect of the present law on young people. It is not a wise law. There is inequity, there is unpredictability, and there is an inflexibility in its present form. These characteristics result in distortions in the use of national resources and in the uneasiness and frustration among young people that make them look evasive in their response to the country’s need. The country’s colleges and its students have long responded to national need and will continue, of course, to do so. But I must list myself with those who feel that urgent action to rectify the present situation is overdue.

VI

M.I.T. has been an achieving institution for its students and for the society because of the intense competence and concern of its Faculty. Once again, the record of the Institute’s year would be incomplete were we not to list the names of those men who now retire as professors and whose contributions to generations of students and to their fields have been outstanding. They are: Herbert L. Beckwith, Professor of Architecture; Martin J. Buerger, Institute Professor and Professor of Mineralogy and Crystallography; Harold E. Edgerton, Institute Professor and Professor of Electrical Measurements; F. Leroy Foster, Director of the Division of Sponsored Research; Nathaniel H. Frank, Professor of Physics; Hoyt C. Hottel, Carbon P. Dubbs Professor of Chemical Engineering; Egon Orowan, Professor of Mechanical Engineering; Edward S. Taylor, Professor of Flight Propulsion; Walter F. Urbach, Associate Professor of Literature; Hurd C. Willett, Professor of Meteorology; and John Wulff, Class of 1922 Professor of Metallurgy.

This year is further marked by the retirement of two of our colleagues from administrative posts, but not, fortunately, from full and active membership on the Faculty. Professor William T. Martin, after 17 years of consistent and constructive leadership as head of the Department of Mathematics, has asked to be relieved of his administrative duties to return to the full-time interests of a professor. Dean Gordon S. Brown, after 20 years of brilliant contribution to engineering administration, education and research, the last ten as Dean of the School of Engineering, has asked, understandably, to be relieved of the pressurized regime of a dean. I will continue to rely on Dean Brown, who becomes Dugald C. Jackson Pro-
fessor of Engineering, for a variety of advice and counsel. The M.I.T. community and I, in any case, have difficulty in adequately expressing our gratitude and our enduring appreciation for all that these two remarkable men at M.I.T. have done for the Institute.

VII

This year has been a full one — a good one, as I have said, by ordinary measures, and one of extraordinary insight for all of us at M.I.T. It is only fitting to note, in closing, that our undergraduates' own characterization of this year, in their choice of the theme for a most unusual and original issue of the yearbook, was a dedication to the "awakening university." Throughout its history, M.I.T. has experienced a continuous awakening, sparked by purpose and committed to the education of leaders who combine enlightened competence with a deep sense of concern for the quality of human life.

These are times of awakened caring, searching concern, and far-reaching expectation. M.I.T. is a vigorous, effective and proud community, sure of its competence, unwilling to rest on its achievements, always insistent on moving ahead. The support of a wider community gives us all — faculty, students, staff, and administration — a full confidence as we look to the next year and beyond.

HOWARD W. JOHNSON

STATISTICS FOR THE YEAR

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1967-68:

REGISTRATION

In 1967-68 student enrollment was 7,730, an increase of 163 over the 7,567 enrolled in 1966-67. This total was comprised of 3,857 undergraduates and 3,873 graduate students.

Graduate students who entered M.I.T. last year held degrees from 303 colleges and universities, 186 American and 117 foreign. The foreign student population was 1,134, representing 14.6 per cent of the total enrolled.* The foreign students were citizens of 78 different countries.

*This count represents all non-citizen students enrolled at the Institute irrespective of visa classifications. It includes, for the first time, all permanent-resident aliens holding immigrant visas.
Degrees awarded by the Institute in 1967-68 included 783 Bachelor's degrees, 731 Master's degrees, 129 Engineer degrees, and 351 doctoral degrees — a total of 1,994.

**STUDENT AID**

This year 2,170 undergraduates, 56 per cent of those enrolled, received $2,800,161 in scholarship aid and $1,391,073 in loans. These two categories of direct aid thus totaled $4,191,234, an increase of 7 per cent over the year before.

The planned use of M.I.T. operating funds in the amount of $317,631 to augment our designated scholarship resources during the past year has helped to make possible this improved aid program. The scholarship assistance granted included $1,147,062 from outside sources (an increase of $85,128 from the previous year) and $1,335,468 from M.I.T.'s own endowment fund. The endowment for undergraduate scholarships was increased by $528,724 during the year. Total endowment for scholarships now stands at $16,057,600, reflecting a 3 per cent increase over 1966-67.

Of the loans provided during the past year, $352,167 came from the Institute's Technology Loan Fund, $573,353 from the National Defense Student Loan Fund, and $223,912 from other private loan funds administered by M.I.T. An additional $241,641 in loan funds was received from other sources.

Besides the loan total recorded above, 200 students (graduate and undergraduate) received $127,930 under the Installment Credit Program, which permits a portion of the tuition fee to be paid over a ten-year period.

During the academic year 1967-68, the Institute made the following awards to graduate students: $2,912,200 in fellowships, traineeships, and scholarships; $919,000 in staff tuition grants; $5,973,000 in staff salaries; and $618,000 in loans, for a total of $10,422,200.

Comparable figures for last year were $2,696,000; $916,000; $5,717,000; and $486,511 respectively, for a total of $9,815,511.

Fellowships awarded to our graduate students in 1967-68 by major outside agencies amounted to an additional $1,996,600. The comparable figure for last year was $1,874,000.

Figures 1 and 2 show the increases over the past decade in most of the foregoing categories of financial aid for both graduate and undergraduate students at the Institute.

**PLACEMENT**

A total of 369 companies, 43 government agencies, and 17 graduate schools actively recruited in the Placement Bureau during the past year.
FIGURE 1

FINANCIAL AID TO UNDERGRADUATE STUDENTS FROM ALL SOURCES, 1958-1968

Thousands of dollars

Loans

Scholarships

The 914 company and other representatives who participated in these visits interviewed a total of 1,652 students, who took 6,758 interviews. Once again a rise was noted in the per cent of our total graduates (all degree levels) who entered business or industry immediately following completion of their degree work. This amounted to 34 per cent. Among our graduating seniors, 65 per cent planned to go on to graduate school, with 24 per cent entering business or industry. The shift in these figures from last year’s (77 and 16 per cent respectively) may be traced to the change in Selective Service regulations announced in February.

Rising at approximately the same level as in recent years was the starting salary for Institute graduates. The median offer to this year’s graduating seniors was $775 per month; to Master’s candidates, $916; and to doctoral candidates, $1,200.

Our Alumni Placement Office saw some reduction in the activity of employers this year, as only 8,825 separate employment opportunities were listed. This reduction from last year is attributed to the national cut-back in spending for research and development which took place last winter and to a slower rate of growth in the national economy.

FINANCES

As reported by the Treasurer, the Institute’s educational and general expenses — excluding the direct expenses of departmental and interdepartmental research and of the Lincoln Laboratory and the Instrumentation Laboratory — amounted to $54,652,000 during 1967-68 as compared to $48,758,000 during 1966-67. The rate of increase of operations in 1967-68 over the previous year was below that of recent years, reflecting the limited resources available for the further expansion in educational and research activities. The Treasurer has pointed out that this increase in educational and general expenses was due in part to special programs such as the growth in basic research financed from private sources, urban affairs, and an extension of computer services.

The direct expenses of general departmental and interdepartmental sponsored research increased from $41,621,000 to $45,680,000; and the direct expenses of major laboratories and special departmental research increased from $103,793,000 to $106,678,000. These changes represent increases of 8.9 per cent and 2.8 per cent, respectively.

The large construction program of the Institute continued to make progress in 1967-68, with the book value of plant facilities increasing from $107,871,000 to $118,798,000.

At the end of the fiscal year, the Institute’s investments, excluding retirement funds, had a book value of $246,458,000 and a market value of
FIGURE 1

THE GROWTH OF MUTUAL FUNDS AND PLANT ASSETS 1955-1968
PRESIDENT

$354,744,000. This compares to book and market totals of $232,151,000 and $332,325,000 last year. Endowment and other funds increased this year from $239,902,000 to $259,882,000.

Funds sharing in the income from the general investments earned 6.7 per cent and 5 per cent was allocated to the endowment funds. In 1967-68 an extra distribution of 2 per cent was made to these funds, as compared with 1 per cent in the preceding year.

Figure 3 shows the growth of M.I.T.'s fund and plant assets from 1958 to 1968.

GIFTS

Gifts, grants and bequests to M.I.T. from private donors totaled $25,881,000 during fiscal 1967-68 as compared with $17,862,000 for the previous year. The former includes continuing payments on the Second Century Fund pledges of $1,514,000, as well as unrestricted direct gifts to the Alumni Fund of $751,000, which made up a part of the total of $2,875,000 included in the Alumni Fund in 1967-68.

PHYSICAL PLANT AND CAMPUS ENVIRONMENT

In the academic year 1967-68, six new buildings were completed and occupied. They are: the Center for Advanced Visual Studies, the Center for Space Research, the Center for Advanced Engineering Study, the Information Processing Services Center, the Eastgate Apartment Tower (providing on-campus housing for married students and faculty) and McCormick Hall East (the second wing of the undergraduate women's residence). In addition, the first phase of the Central Refrigeration Plant was completed and now supplies chilled water for air conditioning to the Center for Advanced Engineering Study, the Center for Space Research, the Information Processing Services Center and the Center for Theoretical Physics.

During the year, work continued on the Chemistry Graduate Research Building, which is now scheduled for completion in 1969. New construction began last year in the following projects: the Engineering Library rehabilitation and renovation, the Linear Accelerator in Middleton, Massachusetts (operated by the Laboratory for Nuclear Science), MacGregor Hall (a new 324-bed undergraduate dormitory facing Memorial Drive on the west campus), and a two-story addition to the Hydrodynamics Building on Vassar Street.

During the year preliminary design work was initiated on several projects, including a new Electrical Engineering Communications Research facility, and site selection studies for an enclosed, year-round tennis facility on the west campus.
PRESIDENT

Noteworthy among the several space alteration and utility expansion projects completed during the past year was the Center for Theoretical Physics on the third and fourth floors of the Eastman Building. This design experiment, in recasting the main corridor arrangement to provide congenial meeting spaces surrounded by clusters of offices, has received a very favorable reaction from the new occupants.

M.I.T.'s physical environment has benefited from major landscaping projects over the past year. They include landscaping for Ashdown House, McCormick Hall, the Bush Building, Ames Street, and the Julie Fassett Memorial Garden. In addition, several new tulip beds and smaller gardens have contributed to the aesthetic environment throughout the Institute.

The Planning Office is conducting major studies on the effect of classroom design on the learning environment and on the uses of color throughout the Institute.

We expect significant improvements in this area in the near future, responding to and supported by an expression of growing student and faculty interest in M.I.T.'s physical environment. Evidence of this interest is the Class of 1968 Gift to the Institute: a new lounge area on the second floor, around the rotunda of the Rogers Building.

PERSONNEL CHANGES FROM
OCTOBER 1, 1967, TO SEPTEMBER 30, 1968

FACULTY AND TEACHING STAFF

DEATHS

CHARLES W. BERRY
Professor Emeritus in Mechanical Engineering

MIGUEL SIDRAUSKI
Assistant Professor in Economics

RETIREMENTS

MARTIN J. BUERGER
Institute Professor Emeritus

HAROLD E. EDGERTON
Institute Professor Emeritus

HERBERT L. BECKWITH
Professor Emeritus in Architecture

NATHANIEL H. FRANK
Professor Emeritus in Physics

HOYT C. HOTTEL
Carbon P. Dubbs Professor Emeritus in Chemical Engineering

EGON OROWAN
Professor Emeritus in Meteorology Engineering

EDWARD S. TAYLOR
Professor Emeritus in Aeronautics and Astronautics

HURD C. WILLETT
Professor Emeritus in Meteorology

JOHN WULFF
Professor Emeritus in Metallurgy and Materials Science and Class of 1922 Professor

WALTER F. URBACH
Associate Professor Emeritus in Humanities

HAROLD H. CARTER
Technical Instructor in Chemical Engineering
PRESIDENT

REIGNATIONS

Professors:
DAYTON E. CARRITT
Geology and Geophysics
NORMAN C. DAHL
Mechanical Engineering
ALLEN FORTE
Humanities
RAYMOND HIDE
Geology and Geophysics
JOHN B. HERSHEY
Geology and Geophysics
CYRUS LEVINTHAL
Biology (to Visiting Professor)
ROBERT A. SMITH
Physics and Director, Center for Materials Science and Engineering

Associate Professors:
JOSEPH ALTMAN
Psychology
JAMES M. BESHES
City and Regional Planning
LESLIE J. DEGROOT
Nutrition and Food Science
ROBERT M. DOWBEN
Biology (to Visiting Associate Professor)
HUBERT L. DREYFUS
Humanities
DONALD E. FARRAR
Sloan School of Management
GORDON P. GARMIRE
Physics
MYRON A. HOFFMAN
Aeronautics and Astronautics
JOHN W. KANWISHER
Geology and Geophysics
WILLIAM B. KEHL
Electrical Engineering
EDWARD S. KLIIMA
Modern Languages and Linguistics
RICHARD H. LEMMER
Physics
JOSEPH PEDLOSKY
Mathematics
CAPTAIN JAMES L. PETTIGREW
Aerospace Studies
CLAES ROOT
Geology and Geophysics
HERBERT D. SALTZSTEIN
Psychology

KARL SHELL
Economics
ABNER E. SHIMONY
Humanities
BARNARD E. SMITH
Sloan School of Management
ALFRED K. SUSSKIND
Electrical Engineering
WALTER R. THORSON
Chemistry
WILLIAM P. TRAVIS
Sloan School of Management
WOLF R. VIETH
Chemical Engineering

Assistant Professors:
ROBERT ADOLPH
Humanities
RAYMOND A. ALVAREZ JR.
Physics
PRANAB K. BARDHAN
Economics (to Visiting Associate Professor)
DAVID E. BERLEW
Sloan School of Management
ALLAN S. DOUGLAS
Chemical Engineering
GIORGIO FIOCCO
Geology and Geophysics (to Research Associate)
DEREK J. FRAY
Metallurgy and Materials Science
THEODORE W. GAMELIN
Mathematics
PETER R. GRAY
Electrical Engineering
WILLIAM H. GRUBER
Sloan School of Management
JOHN C. INGRAHAM
Physics
WILLIAM C. LUTH
Geology and Geophysics
JOHN S. MAULBETSCCH
Mechanical Engineering
POPAT-LAL M.-B. PATEL
Physics
CLIVE H. PERRY
Physics
BRUCE H. POMERANZ
Biology
JACOBO RAPAPORT
Physics
PRESIDENT

DAVID K. ROE
Chemistry

DONALD C. ROYSE
City and Regional Planning

DAVID L. SCHALK
Humanities

JOSEPH J. SCHIFFER
Architecture

JOEL E. SCHINDALL
Electrical Engineering

GEORGE L. SISCOE
Physics

DAVID W. STRANGWAY
Geology and Geophysics

JOHN M. THOMAS
Sloan School of Management

WILLIAM I. THOMPSON
Humanities

JOHN R. WATT
Humanities

T. FERRIS WEBSTER
Geology and Geophysics

R. BRADY WILLIAMSON
Civil Engineering

SAUL A. YANKOFSKY
Biology (to Visiting Assistant Professor)

Assistant Professors and Postdoctoral Fellows:

JOHN N. CHURCHILL
Electrical Engineering

E. EUGENE LEWIS
Nuclear Engineering

DAVID A. DIENER
Chemical Engineering

PROMOTIONS

To Professor:

ALI S. ARGON
Mechanical Engineering

GEORGE BEKEFI
Physics

WILLIAMBERTOZZI
Physics

SYLVAIN BROMBERGER
Humanities

DONALD C. CARROLL
Sloan School of Management

EUGENE E. COVERT
Aeronautics and Astronautics

ERNST G. FRANKEL
Naval Architecture and Marine Engineering

CARL W. GARLAND
Chemistry

LEONARD A. GOULD
Electrical Engineering

FREDERICK C. HENNIE III
Electrical Engineering

ICKO IBEN JR.
Physics

JUSTIN E. KERWIN
Naval Architecture and Marine Engineering

KURT S. LION
Biology

ROBERT E. MACMASTER
Humanities

JAMES E. McCUNE
Aeronautics and Astronautics

WALTER MCKAY
Aeronautics and Astronautics

FREDERIC R. MORGENTHALER
Electrical Engineering

HERBERT H. RICHARDSON
Mechanical Engineering

AUGUSTUS R. ROGOWSKI
Mechanical Engineering

WILLIAM F. SCHREIBER
Electrical Engineering

CAMPBELL L. SEARLE
Electrical Engineering

ARTHUR C. SMITH
Electrical Engineering

EMILY L. WICK
Nutrition and Food Science

To Associate Professor:

ARTHUR E. BERGLES
Mechanical Engineering

HALE V. D. BRADT
Physics

JOHN F. BREEDIS
Metallurgy and Materials Science

JOHN B. BRONZAN
Physics

JOEL E. BROWN
Biology

JAMES D. BRUCE
Electrical Engineering

WILFRED R. CHASSEY
Athletics

FRANKLYN M. CLIKEMAN
Nuclear Engineering

C. ALLIN CORNELL
Civil Engineering
PRESIDENT

CHARLES K. CRAWFORD
Electrical Engineering

MICHAEL L. DERTOUZOS
Electrical Engineering

LAWRENCE B. EVANS
Chemical Engineering

WILLIAM R. FERRELL
Mechanical Engineering

VICTOR W. GUILLEMIN
Mathematics

DAVID M. HERCULES
Chemistry

CHARLES E. HOLT
Biology

PHILLIP ISSENBERG
Nutrition and Food Science

ARTHUR D. KALEDIN
Humanities

ELMER E. LARRABEE
Aeronautics and Astronautics

WALTER H. G. LEWIN
Physics

MARVIN L. MANHEIM
Civil Engineering

CHIANG C. MEI
Civil Engineering

PETER J. PAHL
Civil Engineering

ALLAN D. PIERCE
Mechanical Engineering

JAMES E. POTTER
Aeronautics and Astronautics

JOHN S. SALOMA III
Political Science

HERBERT D. SALTZSTEIN
Psychology

PETER H. SCHILLER
Psychology

ETHAN R. SIGNER
Biology

ROBERT W. SIMPSON
Aeronautics and Astronautics

NATHAN SIVIN
Humanities

AIN A. SONIN
Mechanical Engineering

CHESTER L. SPRAGUE
Architecture

DAVID P. TAYLOR
Sloan School of Management

JAY R. WALTON
Civil Engineering

THOMAS F. WEISS
Electrical Engineering

LEON S. WHITE
Sloan School of Management

GEORGE M. WHITESIDES
Chemistry

RICHARD K. YAMAMOTO
Physics

To Assistant Professor:

ARTHUR B. BAGGEROER
Electrical Engineering

FRANCIS R. COTTRELL
Chemical Engineering

NANCY Z. DWORSKY
Humanities

SHAOU L. EZEKIEL
Aeronautics and Astronautics

JOHN C. GRAVES
Humanities

LEON B. GROISSER
Architecture

WALLACE M. MANHEIMER
Physics

NICHOLAS P. NEGROPONTE
Architecture

JAMES J. NOBLE
Chemical Engineering

WILLIAM L. PORTER
City and Regional Planning and
Architecture

ROSEMARIE S. ROGERS
Political Science

JOHN A. STEFFIAN
Architecture

JOHN D. STEINBRUNER
Political Science

JOSEPH M. SUSSMAN
Civil Engineering

JAN WILLEMES
Electrical Engineering

DANIEL E. WHITNEY
Mechanical Engineering

DAVID N. WORMLEY
Mechanical Engineering

CHANGES OF APPOINTMENT

EDWARD B. ALLEN
Assistant Professor in Architecture

JOHN E. BURCHARD
Dean Emeritus and Professor Emeritus

JOHN BUTTRICK
Assistant Professor in Humanities

JOHN CLARKESON
Visiting Professor in Civil Engineering
PRESIDENT

CHARLES T. COLE
Visiting Associate Professor in Humanities

MILDRED S. DRESSELHAUS
Professor in Electrical Engineering

THOMAS H. DUPREE
Associate Professor in Nuclear Engineering and Physics

SERGIO P. FUBINI
Professor in Physics

MERRILL F. GARRETT
Assistant Professor in Psychology

PAUL E. GRAY
Class of 1922 Professor of Electrical Engineering and Assistant Provost

THOMAS J. LARDNER
Assistant Professor in Mechanical Engineering

WILLIAM A. MARTIN
Assistant Professor in Sloan School of Management

PATRICK MORREAU
Assistant Professor in Architecture

CHARLES A. MYERS
Sloan Fellows Professor of Management in Sloan School of Management

FELIPE OCHOA-ROSSO
Visiting Assistant Professor in Civil Engineering

NORMAN J. PADELFORD
Professor in Political Science and Naval Architecture and Marine Engineering

LISA R. PEATTIE
Associate Professor in City and Regional Planning

PETER B. RHINES
Assistant Professor in Meteorology

LEO SARTORI
Associate Professor in Physics

EDGAR H. SCHEIN
Undergraduate Planning Professor

FRED C. SCHWEPPE
Associate Professor in Electrical Engineering

BARRY B. SPACKS
Visiting Associate Professor in Humanities

HERBERT H. WOODSON
Philip Sporn Professor of Energy Processing in Electrical Engineering

IOANNIS V. YANNAS
du Pont Assistant Professor in Mechanical Engineering

APPOINTMENTS

Professor:

HAYWARD R. ALKER JR.
Political Science

JAGDISH N. BHAGWATI
Economics

BRUNO COPPI
Physics

LAWRENCE S. FRISHKOPF
Electrical Engineering

JOSEPH C. R. LICKLIDER
Electrical Engineering

ELLIOTT H. LIEB
Mathematics

JOHN W. MILNOR
Sloan Professor of Mathematics

WAYNE O'NEIL
Humanities

Associate Professors:

DAVID BALTIMORE
Biology

LEROY L. CHANG
Electrical Engineering

C. FORBES DEWEY JR.
Mechanical Engineering

ROBERT M. FOGELSON
Humanities and City and Regional Planning

MAJOR EUGENE R. HUNTON JR.
Military Science

PADMAKAR P. LELE
Mechanical Engineering and Nutrition and Food Science

KARL LINN
Architecture and City and Regional Planning

KOICHI MASUBUCHI
Naval Architecture and Marine Engineering

MAJOR JOSEPH G. MCCOY JR.
Military Science

MAJOR LEELAND E. PRENTICE
Military Science

ROBERT I. ROTBERG
Political Science and Humanities

ALVIN J. SILK
Sloan School of Management

HAROLD M. STARK
Mathematics

LESTER THUROW
Sloan School of Management and Economics
Assistant Professors:

JONATHAN ALLEN
Electrical Engineering

SUZANNE BERGER
Political Science

WILLIAM K. BERTRAM
Physics

SOW-HSIN CHEN
Nuclear Engineering

JAMES R. CLOW
Physics

MICHAEL S. FELD
Physics

ROBERT S. FREEMAN
Humanities

JULIUS L. GOLDSTEIN
Electrical Engineering

HUGH B. HALES
Chemical Engineering

JOHN B. HEYWOOD
Mechanical Engineering

NORMAN JONES
Naval Architecture and Marine Engineering

RICHARD C. LANZA
Physics

JOHN S. LEWIS
Geology and Geophysics and Chemistry

HARVEY F. LODISH
Biology

HENRY J. LUBATTI
Physics

FRED L. LUCONI
Electrical Engineering

THOMAS B. MCCORD
Geology and Geophysics

DANIEL Q. MILLS
Sloan School of Management

MARK F. NELSON
Civil Engineering

FRANCIS C. O'BRIEN
Athletics

DAVID A. OLIVER
Aeronautics and Astronautics

ALAN L. PATZ
Sloan School of Management

IAN B. RHODES
Electrical Engineering

BARRY H. ROSOF
Metallurgy and Materials Science

RICHARD F. SALANT
Mechanical Engineering

JOHN C. SCHAKE JR.
Civil Engineering

MYRON S. SCHELES
Sloan School of Management

DAVID B. STICKLER
Aeronautics and Astronautics

KEITH I. THOMASSEN
Electrical Engineering

COLIN J. THOMPSON
Mathematics

KOSTA M. TSIPIS
Physics

Assistant Professors and Postdoctoral Fellows:

DAMON E. CUMMINGS
Naval Architecture and Marine Engineering

MICHAEL B. GODFREY
Civil Engineering

ALAA MANSOUR
Naval Architecture and Marine Engineering

RICHARD A. MOSS
Mechanical Engineering

WILLIAM J. SHACK
Mechanical Engineering

APPOINTMENTS OF VISITING FACULTY

Visiting Professors:

R. STEPHEN BERRY
A. D. Little Professor of Chemistry

E. MARGARET BURIDGE
Abby Rockefeller Mauzé Professor of Physics

JOHN W. GARDNER
Germeshausen Professor

HARLAN L. GOERING
Karl Pfister Professor of Chemistry

GEOFFREY D. PARFITT
Dubbs Professor of Electrical Engineering

ISIDOR I. RABI
Karl Taylor Compton Professor of Physics
G. Wilse Robinson
A. D. Little Professor of Chemistry

Donald A. Schon
Ford Professor in City and Regional Planning

Robert C. Seamans Jr.
Jerome Clarke Hunsaker Professor of Aeronautics and Astronautics

J. L. Talmon
Ford Professor in Humanities

Ignacio Tinoco Jr.
A. D. Little Professor of Chemistry

Wayne A. Bowers
Physics

David L. Call
Sloan School of Management and Nutrition and Food Science

Richard W. Conway
Electrical Engineering

Keith S. Donnellan
Humanities

Joseph C. Edozien
Nutrition and Food Science

Charles Fried
Humanities

Ernst Giencke
Civil Engineering

Wolfgang K. Giloi
Electrical Engineering

Kurt Gottfried
Physics

Ernst Halperin
Political Science

Leston L. Havens
Humanities

Allen F. Henry
Nuclear Engineering

Heinrich Hertel
Aeronautics and Astronautics

Morris A. Horowitz
Sloan School of Management

Helio Jaguaribe
Political Science

Lewis D. Kaplan
Geology and Geophysics and Meteorology

Samuel I. Katz
Sloan School of Management

Paul Keckemeti
Political Science

Mikhail N. Kogan
Aeronautics and Astronautics

Maurice Levy-Leboyer
Economics

Nissan Liviatan
Economics

Frank E. Marble
Aeronautics and Astronautics

David C. McClelland
Sloan School of Management

Frank I. Michelman
City and Regional Planning

James A. Mirrlees
Economics

Michael Murray
Humanities

Elliot I. Organick
Electrical Engineering

Jean Paelinck
City and Regional Planning

LaJos Pukanszky
Mathematics

George W. Rathjens
Political Science

Karl A. J. Scheidl
Sloan School of Management

Peter Schofield
Physics

Obaid Siddiqi
Biology

Glucio A. D. Soares
Political Science

Robert Steinberg
Mathematics

Ernst A. Steinhoff
Aeronautics and Astronautics

Lotfi A. Zadeh
Electrical Engineering

Visiting Associate Professors:

Gene A. Baraff
Physics

W. Gary Ernst
Geology and Geophysics

Bhaskar K. Ghosh
Economics

Ronald B. Goldner
Electrical Engineering

Jean G. C. Hanus
Electrical Engineering
### PRESIDENT

- **Suzue Ishii**  
  Mechanical Engineering

- **Michael Judd**  
  Aeronautics and Astronautics

- **Hiroo Kanamori**  
  Geology and Geophysics

- **Banakoppar T. Lingappa**  
  Biology

- **John A. Menge**  
  Sloan School of Management

- **Atsuhiro Nishida**  
  Physics

- **James K. Palmer**  
  Nutrition and Food Science

- **Karl-Heinrich Schrader**  
  Civil Engineering

- **Visiting Assistant Professors:**
  - Marco Crippa  
    Biology
  - David S. Feingold  
    Biology
  - Alan B. Hooper  
    Biology
  - Rafael Kalish  
    Physics
  - Benjamin F. King  
    Sloan School of Management
  - Michael Lipsky  
    Political Science
  - H. N. Mahabala  
    Electrical Engineering
  - Ved P. Mainra  
    Mathematics
  - Rolf Nevald  
    Electrical Engineering
  - Kalluri Ramalingasarma  
    Electrical Engineering
  - K. Sommasundra Rao  
    Chemical Engineering
  - T. Kishan Rao  
    Civil Engineering
  - Hedley J. B. Rees  
    Economics
  - Paul E. Roberts Jr.  
    Sloan School of Management
  - Major John C. Ruth  
    Aeronautics and Astronautics

### BRADBURY SEASHOLES
- Political Science

### GAJENDRA SINGH
- Mechanical Engineering

### ADMINISTRATION

### DEATH

- John K. Dupress  
  Research Associate in Mechanical Engineering

### RETIREMENTS

- Cecile Barsky  
  Cataloger

- John W. Chamberlain  
  Surgeon-in-Chief

- Medical Department

- F. Leroy Foster  
  Director, Division of Sponsored Research

### RESIGNATIONS

- Frank T. Bauchspies  
  Director, Industrial Liaison Office

- William R. Bjerstedt  
  Associate Director, Institutional Studies

- Francis J. Brennan  
  Personnel Assistant, Office of Personnel Relations

- R. Eugene Bullock  
  Assistant Director, Public Relations

- Jeannette C. Doherty  
  Assistant, Institute Real Estate

- Byron A. Drinkwater  
  Assistant Auditor

- Frederic H. Fairchild  
  Administrative Assistant, Department of Electrical Engineering

- Richard H. Forsythe Jr.  
  Associate Auditor

- Peter B. Franz  
  Industrial Liaison Officer

- James D. Hobbs  
  Assistant Safety Engineer

- Thomas J. Kehoe  
  Staff Accountant, Instrumentation Fiscal Office
PRESIDENT

WALTER L. KOLTUN
Special Assistant, Office of the Vice President and Secretary of the Institute, and Institute Secretary for Foundations

GEORGE J. L'A BRECHE JR.
Staff Assistant, Planning Office

JOSEPH J. LAMBERT
Director, Development Office, and Secretary of the Development Council

CAROL J. MARKEY
Interior Designer, Planning Office

DONALD D. MCNEIL
Administrative Officer, Department of Biology

J. DAVID RANEY
Assistant to the Dean, Sloan School of Management

A. WILLIAM SCANNELL JR.
Staff Programmer

LIEUTENANT COLONEL
Jack R. Schields
Head, Department of Military Science

ELLISON W. SMITH
Editor, Office of Public Relations

CAPTAIN ROBERT E. STARK
Head, Department of Naval Science

LEO V. SULLIVAN
Assistant Personnel Officer for Hourly Personnel

JAMES M. THOMPSON
Staff Programmer

BENJAMIN K. T'SOU
Systems Analyst, Institutional Studies

GRAHAM VOADEN
Sales Manager, The M.I.T. Press

PHILIP B. WAINWRIGHT
Project Manager, Physical Plant

EDWARD D. WALSH
Staff Programmer

JENNIFER R. WILDER
Special Assistant to Director, Summer Sessions

GERTRUDE B. WINOQUIST
Manager, Endicott House

JANE L. YUSEN
Systems Analyst, Institutional Studies

APPOINTMENTS AND CHANGES:

NAN ARGHYROS
Registrar of the Collection, Commission on Visual Arts

COLONEL MARSHALL O. BECKER
Head, Department of Military Science

SHEILA B. BEYER
Administrative Assistant, Institute Real Estate Office

LEW F. BOYD
Assistant to the Director, Development Office

KENNETH C. BROWNING
Assistant to the Director, Housing and Dining Service

PAUL H. BURR
Institute Secretary for Foundations

RICHARD J. CALLOGiero
Project Administrator, Planning Office

LEO D. CAPLICE
Administrative Officer, Medical Department

JACK W. CHRISTENSEN
Director, Industrial Liaison Office

WILLIAM H. COMBS
Superintendent of Building Services, Physical Plant

PAUL W. COOK JR.
Consultant to the President of the Institute

STUART H. COWEN
Administrative Director, Division of Sponsored Research, and Director of Fiscal Planning

LALITA DAS
Architect-Programmer, Planning Office

THEODORE M. DOAN JR.
Assistant Superintendent of Building Services, Physical Plant

PETER C. FARRELL
Industrial Liaison Officer

JOHN T. FITCH
Manager, Self-Study Subject Development in Center for Advanced Engineering Study

MARY M. FUREY
Systems Analyst, Institutional Studies

EDWARD J. GAUDIANO
Administrative Officer, Department of Biology
<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Department/Office/Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>President</td>
<td>NICHOLAS J. GRANT</td>
<td>Professor of Metallurgy, and Director, Center for Materials Science and Engineering</td>
</tr>
<tr>
<td></td>
<td>JAMES E. GROSS</td>
<td>Administrative Assistant, Campus Housing</td>
</tr>
<tr>
<td></td>
<td>ELIAS P. GYFTOPOULOS</td>
<td>Acting Head, Department of Nuclear Engineering</td>
</tr>
<tr>
<td></td>
<td>ROBERT L. HALFMAN</td>
<td>Deputy Head, Department of Aeronautics and Astronautics</td>
</tr>
<tr>
<td></td>
<td>WILLIAM J. HECHT</td>
<td>Executive Secretary, Educational Council, and Assistant Director of Admissions</td>
</tr>
<tr>
<td></td>
<td>DAVID H. HENSHAW</td>
<td>Staff Accountant, Comptroller's Accounting</td>
</tr>
<tr>
<td></td>
<td>RICHARD E. HIGHAM</td>
<td>Personnel Assistant, Office of Personnel Relations</td>
</tr>
<tr>
<td></td>
<td>CAPTAIN DEAN A. HORN</td>
<td>Head, Department of Naval Science</td>
</tr>
<tr>
<td></td>
<td>SALLY B. HOWES</td>
<td>Personnel Assistant, Office of Personnel Relations</td>
</tr>
<tr>
<td></td>
<td>JOHN J. HYNES</td>
<td>Staff Accountant</td>
</tr>
<tr>
<td></td>
<td>FRANK S. JONES</td>
<td>Executive Director, Urban Systems Laboratory; Special Assistant to the Office of the President; and Senior Lecturer in Civil Engineering</td>
</tr>
<tr>
<td></td>
<td>KEATINGE KEAYS</td>
<td>Administrative Officer, Department of Naval Architecture and Marine Engineering</td>
</tr>
<tr>
<td></td>
<td>WILLIAM J. KELLEY</td>
<td>Project Manager, Institute Real Estate</td>
</tr>
<tr>
<td></td>
<td>DAVID J. KNEELAND</td>
<td>Staff Accountant, Comptroller's Office</td>
</tr>
<tr>
<td></td>
<td>DANIEL T. LANGDALE</td>
<td>Assistant Director, Student Aid</td>
</tr>
<tr>
<td></td>
<td>SALVATORE LAURICELLA</td>
<td>Administrative Staff, Graduate House Dining Service</td>
</tr>
<tr>
<td></td>
<td>NELSON C. LEES</td>
<td>Director, Development Office</td>
</tr>
<tr>
<td></td>
<td>NORMAN LEVINSON</td>
<td>Head, Department of Mathematics</td>
</tr>
<tr>
<td></td>
<td>JOSEPH C. R. LICKLIDER</td>
<td>Director of Project MAC</td>
</tr>
<tr>
<td></td>
<td>JAMES L. LINDBERMAN</td>
<td>Assistant Director, Institutional Studies</td>
</tr>
<tr>
<td></td>
<td>JOHN L. MATARESE</td>
<td>Staff Accountant, Instrumentation Fiscal Office</td>
</tr>
<tr>
<td></td>
<td>WILLIAM H. MCITEGUE</td>
<td>Director, Educational Council, and Associate Director of Admissions</td>
</tr>
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PRESIDENT

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Assistant Dean of Engineering

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Civil Engineering

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As seen from the data of one year ago, it is evident that the crowded events of the last 12 months have generated a substantial further shift in the outlook and prospects for this School, accelerating trends that had been observed earlier. Traditional values in the environmental professions are fading rapidly; interaction with other professions intensifies; more effort is spent on proposed programs than on the ongoing ones, and already the ten-year projections made in April, 1967, seem out of date.

Development in the Department of Architecture has been accelerated by the efforts of the new Chairman, Professor Donlyn Lyndon, to assess the resources of the Department and match these with his own concerns. The continued awakening of the Institute as a whole toward urban problems is a spur to both departments; applications for admission continue their rapid increase in the Department of City and Regional Planning; the visual arts are more intensely evident; the Center for Advanced Visual Studies has begun to assert its existence. Behind these internal trends lie profound external dislocation and adjustments.

There seems little doubt that our society is undergoing a pronounced reorientation of a sort that comes only at something like half-century intervals. Considered both nationally and globally, there is an approaching crisis in human ecology. To cope with accelerating growth rates and at the same time to improve the quality of life in ways we know to be possible will require more rational allocations of resources and more effective deployment of professional skills. Architecture and planning, concerned as they are with giving order to environmental and social change, will remain under stress as far ahead as can now be seen.
In my report of the year 1965-66, my first year as Dean of this School, I suggested that professionalization in architecture and planning has reached a certain degree of structural hardness, and that further emphasis on internal group solidarity may impede progress. Under these conditions new directions need to be found by looking outward. The justification for professionalism will be redefined through a fresh analysis of problems and through encounters with other professions that address themselves to similar problems.

Much of our professional education has been based on the simple notion of observing how successful practitioners cope with problems in the “real world,” and of using their methods as models for exercises in the classroom and studio. We see this with special clarity now that the usefulness of this type of pedagogy is in sharp decline. In a period of rapid cultural change, young people do not identify the careers of older people as what they would wish to emulate. Students of planning see the old policies of public housing, zoning, and urban renewal as ineffectual, if not sometimes harmful controls on urbanization; students of architecture see the stylish work of prominent architects as ephemeral and irrelevant to the wider problems of environmental improvement. It is disillusioning to see, for example, the prestige of our most distinguished professionals being put to the support of projects like the John Hancock Tower at Coppley Plaza and the skyscraper on top of the Grand Central Building.

A young Mexican architect, Julio Chii Wong, states the case as follows: “The young architect of today knows that the tendencies of the profession cannot and should not be limited simply to satisfying the relationship between the architect and the client; that he is no longer the liberal professional who designs buildings and contributes to the beauty of the city; but that, on the contrary, in exercising this profession he must define the tendencies and objectives according to the needs of community development as a whole, in order to provide the architectural solutions of national and total scope required by these needs.”

Since old-style professionalism has too often addressed the wrong problems, students and faculty alike are becoming suspicious of the merits of theoretical exercises that lead to “correct” solutions on paper, especially when they presume to deal not just with physical phenomena but with the welfare of human beings. The obvious catharsis is to seek problem material through direct interaction with people in their environment. Such a search goes beyond the job in the consultant’s office or in the renewal agency and leads to the creation of entirely new roles in community environment-building. Many failures and frustrations beset this path, but it eventually will lead to more effective professional involvement.
As indicated in the departmental reports, these field activities in environmental development are occurring at many levels. One kind of effort looks toward understanding the dynamics of squatter settlement in cities in the have-not countries; related to it is the concern to overcome conditions generated by race and poverty in our own country, especially in neighborhoods close at hand in Greater Boston. Neither of these situations has hitherto received any significant beneficial activity by our professions. Nor will it be easy to discover beneficial modes, but the task is obviously urgent.

Even more interesting (and disturbing to some) is M.I.T.'s internal environmental ferment. Our university — its curricula, its facilities, its general ambiance — is an institution most of us have taken for granted. Indeed, it is professionalization that has made it so stable as to seem endlessly self-renewing. In every category of interest we can find a qualified professional expert to whom we may look for policy guidance. But it is characteristic of the period now upon us that the community is no longer willing to delegate to experts; it wants to participate. It is important to recognize and to provide creative outlet for this wish. Administrators who insist that things must continue just as they always have lay their institutions open to destructive action, as has occurred in New York and Paris.

Four otherwise unrelated events manifest this new spirit in our School in characteristic ways. First is the action on the part of an extraordinarily mature and demanding group of students to force the reformation of curricular requirements for the M.C.P. degree. Second are the celebrated architectural "mezzanines," which, while trouble-making, are remarkable examples of a kind of mass will to create an environment. Most public in character is the third example, the inspired commemoration of Martin Luther King, in which the design students chose to express their ideas by means of images arranged in space. Finally, I would mention the increasingly successful efforts of Professor Wayne V. Andersen, Professor Gyorgy Kepes, and the Fellows of the Center for Advanced Visual Studies to intensify the experience of the visual arts by involving the viewer in direct participation, as in the events designed by Hans Haacke and Otto Piene.

The foregoing activities short-circuit conventional modes of representing action and go directly to the production of environmental change or artifact. Unless supported by disinterested monitoring and evaluation, they may be too visceral in character to meet the university's standards of objectivity. But there is another broad range of activities that is complementary. These spring from the promise of new methodologies for
problem solving, especially those supported by memory and retrieval systems and manipulative possibilities of the computer. These methods, which already have brought quantification to so many disciplines, are now beginning to revolutionize environmental design. They enable us to grasp a wider statement of the total problem input on something more than an intuitive basis, and to generate a richer choice of solutions.

Symbolic operations serving as models for the solution of real problems run the constant risk of overcodification, of becoming ends rather than means — insufficient attention being paid to their possible loss of relevance in a changing world. The whole operational structure of the beaux arts was invented to systematize methods appropriate to the aspirations of an earlier time; its residual influence remains as an incubus that dampens our enthusiasm for any panacea. New methods must include the feedback that assures continued relevance. It must be our task so to organize the work of the School as always to illuminate the entire process of environmental change, including effectuation of policy in the field and its evaluation in use. Inadequate attention to any link in this chain distorts the overview and reduces the effectiveness of professional action.

Although architecture and planning have been slower than other professions in adopting the powerful tools of computation, the trend is now in full swing. We observe that Professors Aaron Fleisher, Albert G. H. Dietz, John R. Myer, William L. Porter, Nicholas P. Negroponte, and Leon B. Groisser, along with Wren M. McMains, Robert J. Pelletier, Timothy E. Johnson, Calvin F. Opitz, and Jeffrey D. Heller are devoting much of their effort at the Institute to developing computer applications in our field, partly through individual initiative, partly by interaction with the sophisticated work long under way in the Department of Civil Engineering, and increasingly through participation in the newly organized Urban Systems Laboratory.

Computation has many obvious applications in isolated sectors of our work where there is need to organize complex data: social migration, building cost data, construction processes. Yet there will be a limit to the benefit in these manipulations unless we can also come to a better understanding not only of our goals but of the thought processes we use to synthesize solutions compatible with given circumstances. When circumstances have the complexity that surrounds environmental choice, such understanding is extraordinarily difficult. Historically, the impact of computation on other professions has been to force a rationalization of their thinking patterns; this challenge is now ours.

At the close of the academic year the School also finds itself confronting the possibility of a change in its own environment, a relocation that
could provide not only new neighbors but larger quarters for our activities. This situation is the result of M.I.T.'s recent acquisition of an industrial building at the intersection of Wadsworth and Amherst Streets. The building was constructed in the 1930's, is in good structural condition, and contains more than 100,000 square feet of floor area. The School has issued a memorandum containing its first assessment of the degree of its fit to this structure and location, but no decision has been made as of this writing.

LAWRENCE B. ANDERSON

DEPARTMENT OF ARCHITECTURE

During this academic year the interests of the Department have turned increasingly to a set of concerns that no doubt will continue to occupy our attention during coming years.

SPACE-USE INTERACTION

Chief among these are the complicated interactions that exist between space organization and the uses of space. While there is no doubt that the shapes and forms that define spaces among which we live influence the way we behave, it is also evident that there are few patterns of use that can or should be optimized. The designer is left with use requirements that are important but in part indeterminate. However, there are strong patterns of habitual behavior and comparatively rigid limitations on the extent to which potential users can visualize unfamiliar forms of space organization. These factors tend to limit the exploration of environmental possibilities.

It is towards extension of the beginning student's understanding of space-organizing possibilities that Professor Maurice K. Smith's studio has been principally directed. Working within a model construction framework that can readily produce a variety of conditions, students confront the malleability of space and use, as well as the discipline inherent within a system of building.

Professor Chester L. Sprague and his students, in one of the advanced design studios, worked closely with the evolution of spatial requirements for a new pattern of activity — in this case a new school that will use individualized teaching methods. Study of the uses of space in an existing school with similar goals served as the basic observations against which new forms of organization could be compared.
ENIRONMENTAL DEMONSTRATIONS

A much more direct confrontation between form and behavior was made possible through the designation of a space/use workshop and experimental area encompassing the undergraduate design studios and adjoining corridors. With the supervision of a student-faculty-staff committee, our students designed and built their own work spaces, adding to the usable area in the drafting rooms by the construction of a string of mezzanines. The work places so created were then subject to the test of use and revised during the year.

Students who worked in the area encountered the necessity for programming construction procedures, the difficulties of resolving conflicts in neighboring designs, and the consequences for long-term use of their own design decisions. At the same time, the entire project served to demonstrate alternative uses of space.

It has become increasingly clear that demonstration is necessary to engage attention effectively for the establishment of new forms of environment. Encouraged by the potency of experiments constructed in the design studios, a group of fifth-year students chose to continue this form of activity as a combined thesis project. They prepared models for a proposed renovation of space in Building 10 that was approved for construction by the Committee on the Visual Arts, and they were instrumental in preparing a large memorial exhibit that served as a setting for M.I.T.'s observance of the death of Martin Luther King.

These projects were planned, undertaken and studied with the advice and guidance of Professors Karl Linn and Henry A. Millon. A third demonstration project, the refurbishing of a basement vending machine area in Building 7, was undertaken with the support of Professor Wayne V. Andersen.

As Director of Exhibitions and Chairman of the Committee on the Visual Arts, Professor Andersen planned several shows that brought the M.I.T. community into contact with unprecedented environments. The main lobby of Building 7 was used for segments of the Hans Haacke and the Park Place Group shows; each actively transformed the character of the space and engaged participation from passers-by.

DESIGN INFORMATION

In consort with such efforts to extend our understanding of space/use interaction through direct experience, there is increasing attention in the Department to means for improving our ability to use relevant information in the design process. A design information study group has been formed to examine various critical and analytical procedures as they relate to the development of design aids.
DEPARTMENT OF ARCHITECTURE

Work in the history, theory and criticism of architecture under Professors Stanford O. Anderson and Millon is directed toward the establishment of a framework within which to view the relevance of particular information on a scale of cultural values.

Others have been concerned with using the computer to assist in design. Nicholas P. Negroponte and Leon B. Groisser have continued their work on URBAN 5 and have conducted an extremely popular special studies subject, Computer Aided Urban Design, that now will become a regular offering of the Department. This year Timothy E. Johnson offered an introduction to automatic computation of specific relevance for architects; he will work during the coming year under a National Science Foundation grant for continued development of computer aided building design.

BUILDING SYSTEMS

Further study of the design implications of a systematized pattern of construction was supervised in the graduate program by Professor Waclaw P. Zalewski and Visiting Professor Yusing Y. Jung, who replaced Professor Eduardo F. Catalano during his fall term sabbatical leave. Their work concentrated on the coordination of structural and mechanical distribution systems within large buildings for which only the general type of use had been determined.

By limiting the range of considerations, Professor Catalano’s group attempts to clarify the fundamental relationships between decisive factors. Initial steps have been taken to develop computer programs that will allow for quick quantitative analysis of design proposals made within such a limited set of construction systems.

Members of the Building Research Group, working with members of the Department of Civil Engineering, undertook this year to determine the economic, structural, and procedural feasibility of a high-rise construction system that would use jacks to raise completed floors so that all construction activity except interior finish could take place near the ground. This project was sponsored by the United States Steel Corporation.

COMMUNITY DEVELOPMENT STUDIES

The foregoing considerations are relevant to the quality of the environment architects produce and to their skill in predicting the consequences of their design decisions. Of equal importance is the realignment of attention toward problems that have, to date, fallen outside the traditional bounds of the profession. We are convinced that a satisfying environment can no longer be considered either a privilege for the affluent few, or a dispensation from benevolent government.

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This year a considerable segment of the Department’s activity has been concerned with means for extending design and technical assistance to groups that normally do not have access to professional services. Students in an advanced design studio with Professor Robert Goodman spent the year working with the Lower Roxbury Community Corporation in an effort to provide new housing for six families who are now subject to relocation. They studied the particular needs of each family, explored various subsidy programs for financing proposed schemes for new construction, and prepared working documents for the refurbishing of a city-owned apartment building.

On their own initiative, some students have extended this form of activity into the summer and presently are constructing playgrounds in Roxbury and Charlestown.

These activities have gained impetus from the presence of Karl Linn, who joined our faculty this spring as Associate Professor with a joint appointment in the Department of City and Regional Planning. He is preparing an account of his many years of experience with the creation of “neighborhood commons” under a grant from the van Ameringen Foundation.

Master-of-Architecture level studies in housing and community design in developing countries have continued with Ford Foundation support under the direction of Professor Horacio Caminos. They were supplemented this year by John F. C. Turner’s examination of squatter settlements in South America and by a comparative study of residential development patterns in selected communities in Boston and South America, carried out with assistance from John A. Stefflan.

A project for the Blackfeet Indians, initiated in the context of this studio, has developed into a continuing research project directed by Professor Sprague.

**URBAN DESIGN**

Another aspect of changing urban conditions is an increasing concern for the study of extended segments of urban form, often under the impetus of institutional change.

Advanced Bachelor of Architecture students, with Giancarlo de Carlo of Milan as Bemis Visiting Professor, explored possibilities for using the intervention of a decentralized university project as a means for renewing the developmental strength and environmental quality of Boston’s South End.

Another design subject, with Professor Joseph J. Schiffer, studied the development of a community college and its impact on the surrounding
environment in Charlestown. Still another, under Jean-Michel Charuet, Visiting Associate Professor for the fall term, conducted a study of potential new town development on Cape Ann.

The Master of Architecture program in urban design, directed by Professor Jan Lubicz-Nycz, used for a basic study the competition program for a new town in Espoo, Finland. Second-term studies either continued this project in greater detail or were based on current American urban design projects, such as the Illinois Central air rights project on the Chicago waterfront.

This year two urban projects were undertaken in collaboration with other departments. Professor Stanford Anderson and Edward B. Allen worked with Professor Robert W. Simpson of the Department of Aeronautics and Astronautics on environmental planning for V/STOL (Vertical Short Takeoff and Landing) air transportation; and Professors Jung and Zalewski supervised a group of students working with the Department of Naval Architecture and Marine Engineering on the development of water-borne communities.

During the coming year William L. Porter will join our faculty as Assistant Professor to direct, with Professor John R. Myer, the curriculum development research necessary for a significant expansion of our program in this field.

CURRICULAR DEVELOPMENT

Programs in visual design, in history, theory and criticism of the arts, and in creative photography continue to afford valuable opportunities for education in the visual arts and to provide support for the professional program. All are rapidly gaining in momentum. The creative photography program under Professor Minor White is extremely popular and has begun to attract numbers of advanced students. The lively history of art program continues to attract the largest enrollment by non-majors. Establishment this year of the Center for Advanced Visual Studies, under the direction of Professor Gyorgy Kepes, has given clear identity to the significance of visual design at M.I.T.

Within the professional curricula we have continued to explore means for allowing students greater choice in their selection of study areas, while encouraging faculty interests to coalesce in areas of particular concern. During this year, Bachelor of Architecture design studies again were structured to provide a spectrum of problem areas, and each included students from more than one class. For the Master of Architecture program an important decision was made: two years of residence will be required of incoming applicants beginning in September, 1968.
Of special interest was the degree to which student initiative contributed to the program. In addition to the environmental demonstrations and community development activities already mentioned, students, with leadership from Yianni Pyriotis, administered a lively program of outside lecturers.

PROSPECTS

Rapid changes in society, in technology, and in our aspirations for the environment, promise to keep the Department of Architecture in a state of creative perturbance for some years to come. We look with special interest to the augmentation of the urban design program now being initiated and to our expanding involvement with community development in disadvantaged areas. Computer studies by members of the design information group no doubt will continue to increase, while the need for continued experimentation with actual environments is clear. Research into the requirements for a broad program in industrialized construction should be considered soon for curriculum development.

As the awareness of urgent needs presses us ever more firmly, the values of historical distance become more apparent. Our excellent program in history, theory, and criticism of the arts should be expanded immediately to encompass the history of urban form. This, and other areas of research activity, need a channel for advanced study; early consideration should be given to the establishment of a doctoral degree within the Department.

ENROLLMENT

The next few years will be difficult for enrollment records, since the Department is in transition from a five-year undergraduate program to a six-year sequence with a Bachelor of Science in Art and Design at four years and the first professional degree, Bachelor in Architecture, after two years of graduate study. Students completing the old program are still in course, while adherents to the new program are on the increase.

In 1966-67, there were 96 undergraduate candidates for the Bachelor of Architecture, but this number diminished to 52 in 1967-68. Candidates for the Bachelor of Science in Art and Design increased from 1 to 30, while the enrollment of graduate student candidates for the Bachelor of Architecture increased from 19 to 37. These shifts approximately offset each other, and since candidates for the Master of Architecture remained stable (37 in 1966-67, 35 in 1967-68), the population of degree candidates has not changed notably (153 in 1966-67, 154 in 1967-68) although Special Students have increased from 12 in 1966-67 to 29 in 1967-68.
During the year the following degrees were awarded: Bachelor of Science in Art and Design, 1; Bachelor of Architecture, 25; and Master of Architecture, 17.

FACULTY CHANGES
Professor Myer was on sabbatical leave during the entire year, and was able to carry out a study trip to Japan. Professors Herbert L. Beckwith, Catalano, and Smith were beneficiaries of one-term leaves of absence. Professor Schiffer resigned, following nine years of valuable service in design studio teaching and curriculum development.

Visiting Professors De Carlo, Jung, and Charuet have been mentioned, as have Professor Linn, Mr. Johnson, and Mr. Allen as new members of the staff. William H. Wilson has served a one-year part-time appointment as instructor in the history of the visual arts. Rosalind E. Krauss, a candidate for the Ph.D. in Fine Arts at Harvard, has joined the faculty part-time and will continue on a full-time basis in 1968-69. Patrick Morreau has served as studio critic in structures.

The end of this academic year marks the retirement of Professor Beckwith following 42 years of service to the Institute. As Professor of Architecture, as director of the M.I.T. Museum, and as professional consultant for numerous problems of design on campus, he has left a lasting mark on the M.I.T. environment.

DONLYN LYNDON

DEPARTMENT OF CITY AND REGIONAL PLANNING
Like our cities, the Department of City and Regional Planning is experiencing uncomfortable rates of both growth and change. A symptom is the 50 per cent increase in applications for graduate study, bringing the ratio of applicants to available places for next September to ten to one. Another symptom is the tripling of research funds in the past year. (These discomforts are not without compensations.)

The growth and the change are consequences of the surge of our society's concern for its urban problems in recent years, and also of the response to this surge by M.I.T. and by the Department itself.

Thirty-five years ago this graduate program began with the view that city planning dealt with achieving social benefits by changes only in the physical environment; the first students were restricted to architects. Over the years, under the guidance of Professor Emeritus Frederick J. Adams, the program became more and more interdisciplinary. The mix of stu-
SCHOOL OF ARCHITECTURE AND PLANNING

dents extended first to engineers, and later to social scientists and other fields; today it is about a third from architecture and engineering, a third from political science, economics, and such social sciences, and a third from liberal arts, mathematics, geography, psychology, and still other areas. The staff reflects a similar evolution; now numbering 25 (counting seven joint appointments with four other departments, plus a half-dozen part-time lecturers), it includes eight with original degrees in architecture or engineering, 11 from economics, sociology, and anthropology, and six from natural science, psychology, law, and the liberal arts — of the 25, only eight have further Master’s or doctoral degrees in planning as such.

These shifts reflect the changing nature of the city planning field. Physical environmental change remains a strong element, but is now balanced by an equally strong thrust to plan and accomplish social change directly, as well as — and in concert with — socially valuable economic and physical change. The issues of race and poverty, of undereducation and underemployment, of psychological and political alienation — these are now direct objects of city planning, both in American cities and in the underdeveloped countries, rather than the beneficiaries of hoped-for side-effects from slum clearance, housing-construction programs, school and playground designing, transportation improvements, and zoning and subdivision controls.

The Department, however, has not merely reflected the changing nature of the perception of our urban problems, but has been in the forefront of efforts to shift the focus of the planning profession and to adapt planning education to current and foreseeable changing needs.

Along with the shifts in focus have come shifts in method. When our program started, city planning was an intuitive art; it has become gradually, and still only partially, equipped with the working tools of a science or a technology. Relevant research has developed slowly, with an invaluable boost from the Joint Center for Urban Studies since 1959, and the very recent availability of belated Federal and foundation grants in more generous amounts. The present balance of time between teaching and research for our full-time staff members is about 60:40, with, of course, increasing difficulty in distinguishing the two.

A dozen years ago the Department identified its small research activity as a “Center for Urban Studies.” This year the expanded set of operations has been renamed as our Laboratory for Environmental Studies. Its four divisions correspond to the Department’s four directions of development: race and poverty — problems of social change; quality of the physical environment — city design, health, conservation, and so on; lagging countries and regions — problems of economic, social, and physi-
DEPARTMENT OF CITY AND REGIONAL PLANNING

cal development; and information systems and decision making — collecting, analyzing, and manipulating data. Work in progress is supported in part by the Joint Center for Urban Studies, in part by the new M.I.T. Urban Systems Laboratory (under the Ford Foundation Urban Affairs Grant), and in part by outside contracts, for example with the Department of Housing and Urban Development (HUD).

The educational curricula have responded to the changing intellectual climate as well as to changes in focus. The developing body of theory and methodology is displacing an older reliance on principles and practice. With the increase both in number and in variety of multidisciplinary staff, student body, and subjects, specializations have evolved. The requirements for the professional degree, Master in City Planning (M.C.P.), have been under continual revision, gradually eroding the common core of Course work once required of all degree candidates. This year the final step was taken. In the language of city building codes, we have substituted performance requirements for specification requirements. Each M.C.P. candidate will design a Course program with an advisor as Ph.D. candidates now do, not to include specified subjects required of all, but to achieve a common level of competence and core of knowledge, and a deeper competence in some specialization. The stated “requirement” now reads:

1. A general understanding of contemporary urban society and its major components: social, economic, spatial, and political.
2. Skill in the techniques for analyzing urban and regional communities: their social and economic characteristics, spatial patterns, political structure, behavioral impact, and processes of change.
3. Skill in the synthesis of development policy, including the statement of the problem, the formulation of objectives, the generation and evaluation of alternative plans and policies, their implementation, and the monitoring and adjustment of action.

The occasion of this change in departmental rules could be called a student revolt. It was an exceedingly well-mannered and good-humored confrontation, and the resulting new regulations were adopted — after months of open and closed discussion — with full support of both older and younger faculty. But the students earned the credit for initiating the timely reform.

SPURS

In this, its first year, the Special Program in Urban and Regional Studies for Developing Areas (SPURS) enrolled a dozen Special Students from all over the world: Asia, South America, Africa, Europe, and the Agency for
International Development (AID) staff in Washington. Supported by the Ford Foundation International Grant to M.I.T., it provides a year of intensive exposure for mid-career professionals in planning for developing countries. Two of this year's students are staying on for further work toward degrees — an Indian and a Ghanaian.

A number of the Department's regular students were also involved in the seminars growing out of this program, reflecting the substantial interest of our American students in work in developing countries.

Further financial support is being sought, primarily for fellowships, not covered by present funding, to attract applicants from countries unable to finance their participants. Professor Lloyd Rodwin initiated and is directing this program.

CURRICULUM

Additions of subject titles are only one evidence of curricular change; continual revision of the content of older subjects is probably more significant, but difficult to pinpoint.

In the area of city design, in addition to Professor Kevin A. Lynch's seminars and workshops, Professor Stephen M. Carr and Dr. Mary C. Potter (psychologist) are expanding the seminar, Psychological Functions of Environmental Form, to a two-term sequence.

In developing-areas planning, the SPURS program added to Professor Rodwin's subjects new seminars by Dr. Lisa R. Peattie (anthropologist) and Lecturer John F. C. Turner (architect, specialist in squatter housing).

In the social planning area, a new seminar, Deliberate Social Change in the Cities, was begun by Dr. Donald A. Schon of the Organization for Social and Technical Innovation (osTI), who will be Ford Visiting Professor next year (part-time). This seminar was complemented by subject offerings of Professors Bernard J. Frieden and James M. Beshers and new workshop subjects (under old numbers) by Professors Carr and Langley C. Keyes. Professor Frieden also directed this Department's end of the interdepartmental doctoral program with the Department of Political Science, funded by the National Institutes of Health.

In quantitative methods, Instructor Wren M. McMains taught two new seminars in computer methods for city planning, and helped many students to apply the computer to theses and other Course work. Dr. Robert S. Weiss presented Methods of Research in City Planning from a social-science-research perspective.

In economics, Professor Jerome Rothenberg, who holds a joint appointment with the Department of Economics, expanded his offerings in Urban Economics into a three-term sequence, with Professor John R.
Harris of the Department of Economics in charge of the first term. A cooperative doctoral program between the two departments was also developed.

RESEARCH

This year has seen a gradual shift from individual faculty research efforts — in most cases supported by the "free" funds of the Joint Center — toward "projects," involving several staff people, graduate student research assistants, and D.S.R. personnel. Within the Laboratory for Environmental Studies, with Professor Rodwin acting as director, the scale of operations has increased several-fold.

Professor Lynch is engaged in a major study of the potential urban development of the Boston Harbor Islands, an interdepartmental operation sponsored by the Massachusetts Harbor Commission.

In the city design area, Professor Carr is engaged in a study, focused on teen-agers, toward methods by which various groups can identify their needs and desires relevant to spatial form. Dr. Potter is experimenting with the capacity of subjects to analyze and retain visual information from brief observations. Both are components of the larger research field of the effects of urban environment on social and psychological behavior.

Professor Frieden continued his research on relationships between urban planning and health service planning, together with Professor William Nash of Harvard University.

A study of the mobility of the poor, sponsored by HUD, is under the direction of Professor Aaron Fleisher, with the help of Lecturer Philip B. Herr. Professor Fleisher and Mr. McMains have extended their work in acquisition and organization of an urban data laboratory with support from IBM grants to M.I.T. and allocations from the Urban Systems Laboratory.

Professor Fleisher also is engaged in developing the use of the computer to aid in city design; he has worked with William L. Porter, who will join the faculty next year and continue this effort, which includes graphic input and output.

Professor Beshers continued his work on computer models of U.S. internal migration and on computer-based social data management, and participated in the Joint Center project to develop health information systems for the Boston region.

In the area of economics, Lecturer Alexander Ganz completed a study of emerging patterns of U.S. urban growth and transportation needs financed by a General Motors grant to M.I.T., and embarked on a projection of urban development patterns for the New England Economic Research Foundation.
A two-year grant from the Economic Development Administration for a study of various aspects of urban economics, with immediate stress on ghettos, also will involve Mr. Ganz, as well as Professors Rodwin, Rothenberg, and Frieden, Mrs. Peattie, and faculty from the Department of Economics.

The mix of projects ranges across the wide variety of interests of our faculty, but the main thrust in terms of manpower and financing is toward meeting the problems of poor people in poor areas.

SPECIAL EVENTS
The Department was involved heavily in the mid-December, two-day all-M.I.T. conference on the Institute's participation in urban affairs. On April 2, the Department mounted an Industrial Liaison Symposium, "The Role of Industry in the Urban Challenge"; it devised the program and provided five of the six speakers.

Professor Adams again directed the two-week Special Summer Program of in-service training to planners, with a special emphasis on air transport facilities. He was aided by faculty from the Department of Aeronautics and Astronautics.

FACULTY SERVICE
M.I.T. faculty committees involved many of the Department's personnel: Graduate School Policy, Professor Fleisher; Library Advisory Board, Professor Beshers; Operations Research, Professor Fleisher; Transportation, Professor John T. Howard; Joint Center, Professors Rodwin (Chairman) and Howard; Community Service, Professors Frieden (Chairman) and Lynch; Foreign Scholarships, Professor Beshers; Visual Arts, Professor Lynch; and the Urban Coordinating Group, Professor Rodwin. A few of these assignments are normal, necessary, but hardly routine elements in M.I.T.'s working machinery. Most, however, involve substantive work in areas and directions central to the Department's academic concerns, especially the Urban Coordinating Group, the Joint Center Faculty Policy Committee, and the Community Service Committee — the last of these consumed the equivalent of three and a half months of Professor Frieden's time.

Outside of M.I.T., in addition to the normal production of books, articles, and conference papers, the full-time faculty averaged ten days apiece of uncompensated service to professional societies, government committees, and community service. An example is Professor Howard's appointment by Governor John A. Volpe as chairman of an advisory committee to review the Massachusetts planning and zoning laws. Outside consulting averaged an additional 20 to 25 days.
DEPARTMENT OF CITY AND REGIONAL PLANNING

STAFF CHANGES

Dr. James M. Beshers, Associate Professor of Sociology in the Department for the past five years, has resigned to join the faculty of Queens College of the City University of New York. His contribution has been substantial, both in teaching and in research; he will be very difficult to replace.

New to the faculty last September were Assistant Professors Langley C. Keyes and Donald C. Royse, both products of our doctoral program. Professor Keyes is developing work in housing and social problems. Professor Royse, who taught site planning and representation, has accepted a faculty appointment in urban design at Washington University.

Associate Professor Karl Linn joined the faculty early this spring, a joint appointment with the Department of Architecture. With a background in both landscape architecture and psychology, he has done most interesting work in engaging people of poverty areas in changing their immediate environment themselves, especially in small parks and playgrounds.

As Visiting Professor part-time in the fall term, Benjamin Chinitz, Chairman of the Economics Department at Brown University, taught our basic subject in urban land economics. His graciousness in consenting to plug a hole on short notice earned our deep gratitude.

Two new full-time lecturers joined the staff last September. Dr. Mary C. Potter, psychologist, is engaged in both teaching and research in city design. Architect John F. C. Turner, with long experience in squatter housing in South America, was given a joint appointment with the Department of Architecture to work in the developing-countries programs in both departments.

New strength in the social planning area was added in the spring term. Dr. Donald A. Schon offered his new seminar in deliberate social change in the city, to be expanded next year. Dr. Robert S. Weiss, sociologist, taught a subject in social-science research methods.

Senior Visiting Lecturer Lewis H. Weinstein, distinguished lawyer and civic figure, has taught our subject in planning law for the past several years; he will not return next year. To take his place we have recruited Professor Frank I. Michelman of the Harvard Law School, part-time for the fall term.

For the coming year six further new appointments have been made. As Visiting Professor of urban and regional economics, Jean Paelinck of the Faculté des Sciences Economiques et Sociales, Namur, Belgium, will spend a sabbatical leave here on a joint appointment with the Department of Economics, and the Joint Center. Dr. Robert M. Fogelson
has been appointed jointly with the Department of Humanities and the Joint Center as Associate Professor of History and City Planning. Assistant Professor William L. Porter, about to complete our doctoral degree, will hold joint appointment with the Department of Architecture in city and urban design.

Dr. Morris Axelrod, who will head the Joint Center's new Boston Social Survey Project, will hold a part-time teaching appointment as Senior Lecturer in three departments: Management, Political Science, and Planning. Dr. Michael D. Appleby will be a full-time Instructor in workshop and other subjects for the fall term, and in the fall Mrs. Gail B. Hall will teach what was Professor Beshers' urban sociology subject as a part-time instructor.

**PROSPECTS**

The Department has charted a course of further growth and development, for which resources are being sought. The aim is to strengthen our effectiveness in the four high-priority growth areas to which we are already committed:

1. Race and poverty — the problems of social and economic change.
2. Quality of the physical environment — city design, health, conservation, the interaction of human activities with their surroundings.
3. Lagging countries and regions — problems of economic, social, and physical development in industrializing countries and in declining areas of developing countries.
4. Information systems and decision making — the problems of collecting, analyzing, and manipulating data relevant and useful in urban and regional decisions.

To further our general activities of teaching and research in these four areas, we seek again to double our graduate enrollment over the next six years, as we did over the last six. The great number of highly qualified applicants would make this immediately possible without reduction of quality, if the space and teaching resources were available. We seek also to double our faculty and staff, adding both established and promising younger scholars and professionals — in some cases by appointment of core people entirely within the Department, and in others by joint appointments in closely related and essential disciplines, taking advantage of the rapidly growing concern with urban affairs in other departments.

Specifically, we are proposing three new programs, plus a drastic expansion of a fourth:

1. Special program for community leaders. An intensive year of education at M.I.T. for exceptionally promising community leaders, pre-
dominantly from black communities, patterned on our present SPURS
program for students from developing countries. Directed at technical
training needed for effective management of a wide variety of community
activities which will grow with the increase of local influence and control
over public policy, this program not only can meet a clear national
need but also can benefit our regular students and faculty greatly.
2. Undergraduate program in urban studies. An introduction to gradu-
ate study in any of several fields that focus on urban problems (city
planning, architecture, urban politics, civil engineering, urban eco-
nomics), as well as direct preparation for many subprofessional jobs.
This Department, with the necessary interdisciplinary mix within our
faculty, is the appropriate focus for an undergraduate program in urban
studies, not as a substitute for more specialized programs evolving in
other departments, but in collaboration with them.
3. Program of advanced study. Mid-career and postdoctoral study for
urban planners and for professionals from other fields entering urban
affairs. Generally, a year of advanced study might combine serving the
specialized educational needs of such persons with contributing to our
ongoing teaching, research, and field work.
4. Teaching laboratory and field work center. Further major expansion
of the Laboratory for Environmental Studies as an adjunct to existing
graduate teaching and to the new programs listed above, supporting
studies and experiments directly contributory to our high-priority areas
for teaching noted earlier. Especially needed are the development of
field work opportunities and technical capacity in social survey work,
and extension of ongoing work in computer aided design and data pro-
cessing, and in behavioral impact of environment.

The Department has devoted substantial effort this year to developing
these prospects, and to reviewing and revising them in consultation with
the M.I.T. administration and with other departments. We see these
expansions as our best contribution to M.I.T.'s growing commitment
to urban studies, itself a vital element of our society's response to the
critical urban and regional problems of the United States and, indeed,
of the urbanizing world.

JOHN T. HOWARD

CENTER FOR ADVANCED VISUAL STUDIES

With the end of the year 1967-68, the Center will complete, theoretically,
its first year of existence — though in fact the Center work life is hardly
five months old. We moved into our building at the end of October, 1967,
but because of the inevitable difficulties in domesticating a new space, it
took a considerable amount of time to get the studios, workshop, and darkroom in complete working order. Not until the end of November could the work begin, when our first appointed artist-Fellow, Harold Tovish, arrived at the Center.

Four Fellows, mature artists of international stature, were appointed for this academic year. Besides Harold Tovish, they are Otto Piene, Will A. Garnett, and Vassilakis Takis. By mutual agreement, Will Garnett’s participation in the Center is arranged on a part-time basis so that he will be left free to complete a previous commitment to a major project. This project concerns photographing and publishing, in book form, aerial vistas of the fast-disappearing natural landscape of the United States. The pioneer filmmaker, John Whitney, was also invited as a Fellow; but because of budget limitations his coming has had to be postponed until there are sufficient funds to guarantee his living and work expenses. Two new Fellows appointed for the coming academic year are Ted Kraynik of the University of Wisconsin, who is interested in utilizing electronic tools for sculptural forms; and Jack W. Burnham, a light and kinetic sculptor and author of *Beyond Modern Sculpture*, published by George Braziller, Inc.

The initial program of the Center is made up of three interconnected activities. The first consists of the individual artist’s free creative exploration. It is agreed that each artist has the freedom to put a considerable proportion of his creative work time into self-chosen individual tasks. Harold Tovish has been preparing a major sculpture for his current retrospective exhibition at the Solomon R. Guggenheim Museum in New York. Takis is working on his magnetic sculptures for a major one-man exhibition scheduled for next November at the Hayden Gallery. Otto Piene has been working on an environmental sculpture for an exhibition at the Albright-Knox Museum in Buffalo, and more recently on a large-scale experimental night sculpture involving inflated airborne forms presented at the M.I.T. athletic field.

The insights gained by these individual creative pursuits converge in cooperative projects aimed at the creation of monumental scale environmental forms. There are two such projects under consideration. One is a kinetic light form on an imposing scale, hopefully to be realized in Boston Harbor. Its purpose is to provide the urban environment with a focal hearth, a monumental gateway matched to the age of flight. But this projected form is intended to be more than an exciting formal acrobatic utilizing sophisticated technical means; it aspires to have a vital symbolic power. If our ambitions can be realized, it could play a significant role in the Boston celebration of the 200th anniversary of 1776. The
development of such a complex form challenges not only the artist, but also the structural, electronic, computer and systems engineer, the city planner, the psychologist and sociologist. It will involve the solution of a sequence of demanding problems, for this intense animated light form has to be visually intelligible and effective from land, sea, and air, from varying distances, and in changing weather; and it has to satisfy existing and potential needs of our urban life.

The second cooperative project is on a smaller scale. It is the designing of a fountain on the M.I.T. grounds which, by utilizing new technical means, aims to create a choreography with liquids of various viscosity animated by programmed light effects of stroboscopic and other sources.

The Fellows and the director have weekly meetings to discuss the technical and artistic aspects of these projects as well as their social and urban implications. These meetings are sometimes attended by scientists and engineers invited from the Institute, and are tape-recorded. Preliminary plans have been made with Carroll G. Bowen of The M.I.T. Press for semi-annual illustrated publications of the ideas emerging from these cooperative explorative discussions.

The Fellows have been supported in the development of their ideas by the generous advice of Professors Harold E. Edgerton, Norman C. Dahl, Ain A. Sonin and Walter H. G. Lewin.

The third area of the Center's activity is carried out by graduate students and Special Students working with the director on studies supplementing the major cooperative projects of the Fellows. One group of graduate students from the School of Architecture and Planning has been working on models of some suggested kinetic light forms for the Boston Harbor; another is working on a motion picture documentary of some aspects of the functional and aesthetic nature of the night illumination in Boston. The Joint Center for Urban Studies generously underwrote the expenses of the film material and processing.

The major necessary involvement these last two months of existence has been the organization of a dedication symposium, the publication of a booklet presenting the objectives of the Center, and the preparation of an exhibition for the open house for the dedication ceremonies. These activities were most successful in making the Center's goals and its present activities known to the community at large, and were most favorably received.

The over-all positive response to the dedication symposium encouraged us to plan similar yearly symposia. The director has applied for funds from the National Endowment for the Humanities for this purpose, and has received an encouraging response.
Surveying our short life here, we can state with confidence that the spirit of the Fellows and the character of the work produced within the short time that the Center has been in existence has been more than gratifying. Our only concern is the lack of sufficient financial support to guarantee proceeding with our work on the scale that the work warrants. The funds that the Center has received to date have included a starter grant from the Old Dominion Foundation of $100,000 in 1965; a number of smaller grants including a $15,000 donation from Mr. and Mrs. Eugene McDermott; and a recent $40,000 grant for fellowships from the Graham Foundation in Chicago. In order to keep the caliber of artist-Fellows who can make the Center a significant enterprise both within the M.I.T. community and on a broader international scale, as well as provide the optimum conditions for their work, the Center will continue to seek a substantial amount of outside support. With all the support that the Center has received, the existence of the Center is still not financed on a continuing basis. This is a situation that creates obvious difficulties because it does not allow it to make long-range commitments.

An essential urgent need is to have support for equipment and materials for experimentation, including funds for the fabrication of large-scale models by which we can test our ideas.

STAFF

The staff and Fellows of the Center have been involved in the following activities external to those of the Center:

Professor Kepes received the 1968 Fine Arts Medal of the American Institute of Architects and was elected a member of the American Academy of Arts and Letters and the National Institute of Arts and Letters. He received the 1967 Citation for distinguished contribution to art from the National Association of Schools of Art. He served as a member of the Commission on the Humanities in the Schools, under the National Endowment for the Humanities. Paintings by Professor Kepes were acquired by the Smith College Museum of Art, the Worcester Art Museum, and the Art Institute of Chicago. He was invited to design an exhibition on the urban nightscape for the Triennale di Milano. The Saidenberg Gallery in New York exhibited a one-man show by Professor Kepes. He participated in an exhibition by newly elected members of the American Academy of Arts and Letters and the National Institute of Arts and Letters.

One-man shows by Otto Piene were held at the Museum am Ostwall, Dortmund, Germany; in Zagreb, Yugoslavia, and at Studio F, Ulm, Germany. He participated in the following group shows: "Light and
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Motion," at the Worcester Art Museum; "Light and Movement" at the Flint, Michigan, Institute of Art; "Light Sculpture" at the Cleveland Museum of Art; "Light as a Creative Medium" at the Virginia Museum of Fine Arts and at Hemisfair, San Antonio, Texas; and "Kinetic Art" at the German Pavilion, Expo '67, Montreal. His inflation environment, "Pneumatic Garden of Eden," was commissioned for "Plus X Minus: Today's ½ Century," Albright-Knox Art Gallery, Buffalo, New York. The Piene play, "deutschland, deutschland," was performed at the Museum am Ostwall, Dortmund. Performances of "The Proliferation of the Sun" were given at Galerie Art Intermedia, Cologne, Germany; Cologne Academy of Fine Arts; Braunschweig Oberlin College (Allen Art Museum), and The Black Gate Theater, New York. His experiment, "Light Line," was performed with the cooperation of the Center for Space Research, at Briggs Athletic Field at M.I.T., May 22.


Exhibits by Takis appeared in the following: Ex Amsterdam Gallery-Krikhaar; Gallery Claude Givaudan; Centre Culturel Toulouse, Bordeaux, France; Arts-Laboratory Gallery, London; New Institute Gallery, Birmingham, England; Schwarz Gallery, Milan, Italy; Centre Culturel de Le Havre, France; Kunst Forum in Siegfried Gerth, Germany; Maeght Museum, Aix-en-Provence, France; Triennale di Milano with Mr. Wood, Architect; Musée de St. Etienne; Museum of Modern Art; Paris; Maison de la Culture, Amiens, France; Documenta Exhibit, Kessel, Germany; and M.I.T.'s Hayden Gallery.

Harold Tovish received a fellowship of the John Simon Guggenheim Memorial Foundation for 1967. A survey exhibition of sculpture and drawings by Mr. Tovish was held at the Solomon Guggenheim Museum in New York, and the Alpha Gallery in Boston displayed his drawings. He lectured at the Rhode Island School of Design and participated in the Symposium on Art, Science, and Technology at M.I.T. Articles on Mr. Tovish appeared in Boston Arts and Boston Magazine.

GYORGY KEPES

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The year 1967-68 has brought to light an increasing body of evidence that supports our recent efforts to expand the involvement of both faculty and students in problems that directly touch our daily lives. As our activities have broadened and matured in such fields as the matching and application of technology to urban needs, the development of improved health care systems, and the amelioration of air pollution, the role of M.I.T.'s School of Engineering as an agent for public service has become more visible.

In our report last year we noted that these developing activities place a new challenge before M.I.T., that they introduce new value systems, that they present new problems and offer new rewards. But our participation in them must not be a substitute for our traditional activities of pursuing scholarship in depth and of teaching. Our basic concern for excellence in all facets of science and engineering science must not slacken.

We are not alone in holding these views, as evidenced by the fact that the public service aspect of university activity was the central topic of discussion at the 61st annual meeting of the Carnegie Foundation for the Advancement of Teaching. The essay entitled "The University at the Service of Society," reprinted from the 1966-67 Annual Report of the Foundation, is an informal summary of a broadly ranging discussion. It is stimulating and profitable reading, and we recommend it for today's engineering educators. This essay closes with the following paragraph:

Thus the formulation of a satisfactory philosophy of public service is a task of the greatest urgency. It is, at the same time, one of the most difficult assignments facing the American university today. On the one hand, the university must remain faithful to its highest ideal, the pursuit of learning; on the other, it must be responsive
to the legitimate needs of the society that sustains it. Furthermore, it has a responsibility to make that society a better society. Perhaps the simplest and most satisfactory precept for most institutions to follow is to participate, if possible, only in public service activities that are a direct outgrowth of their regular teaching and research programs and that, in turn, feed back into and strengthen them. Obviously this precept is not applicable in each of the many and various situations which arise today, but it does offer initial guidance in coping with a pressing, complex issue.

It is no longer possible to read the daily newspaper without being reminded of these matters. On March 28, 1968, for example, the Christian Science Monitor reported that Sweden was asking the United Nations to convene an international conference on "the problems of human environment." The Swedish delegation expanded on this statement by saying:

The change in the natural surroundings of man brought about without adequate control, by the use of modern technological advances in industry and agriculture . . . and the impact of this process on man himself . . . mushrooming shantytowns and other types of slum areas, as well as rapid urban growth as such, cause not only air pollution and traffic congestion, a damaging level of noise, and sharply increased accident rates, but also problems connected with family disorganization, mental tensions, and increased crime rates. In the past — the diplomats say — such problems were considered totally outside the realm of international affairs. Today it is widely recognized that they have a deep political impact.

We say that, in the past, concern for such problems was considered to be almost totally outside the realm of engineering. We say today, however, the situation is different; our graduates will be involved in all of them.

The key phrase here is our graduates will be involved; and in order for our graduates to cope with the problems of the world in which they will live, their education should have relevance to their times. Hence the educational establishment should embrace authentic real-world activities that permit, in addition to the traditional activities oriented mainly toward scholarship, the involvement of students, faculty, and even the university as a whole. The Carnegie Foundation discussion points out, "... the application of knowledge is no longer a simple matter. So complex has this process become in many fields that the university's help is needed there also." We conclude from such statements that involvement should be in active, rather than passive ways.

We like to think of modern engineers as catalysts to social progress. As the primary creators of wealth, they hold the key to the long overdue actions that are needed and must be taken in response to the problems of urban decay, population explosion, food shortage, traffic jams, environmental pollution, and the social unrest that develops wherever people realize that others in the world enjoy greater economic stability and
higher living standards than they do. As Dr. Karl T. Compton once said, the contributions of engineers and scientists offer nations and people the greatest hope for achieving abundance without resorting to the age-old practice of stealing it from others.

We repeat again the comment by our colleague, Dr. Elting E. Morrison, "... doing engineering is practicing the art of the organized forcing of technological change." We are living in a man-made world. We need to remember that nature's basic law is not just cause and effect, but cause and effect plus feedback. Furthermore, this simple process is attended by a multitude of effects that at first seem secondary, yet frequently are decisive simply because the engineer works just as much with people and their aspirations as with principles and with things. His actions are just as apt to have social, political or economic overtones as technological overtones.

We can, if we will, build in our minds models of a world and social systems that we know will be better. We can sharpen our powers of discrimination and direct our energies at problems of true significance. We can see these aspirations realized if we will move aggressively from being part of the problem to being part of the answer. This we will call "doing engineering to achieve the change to the new society."

**ACTIONS SPEAK LOUDER THAN WORDS**

The reports this year by the heads of departments describe many activities that relate to the above issues. In what follows we will highlight a few items by commenting briefly on our activity under the headings of Engineering and Living Systems — bio-engineering to some people — and of Involvement in Urban Affairs, our new Urban Systems Laboratory and related work.

**ENGINEERING AND LIVING SYSTEMS**

On May 13, 1964, a school-wide committee was appointed to appraise the interests of faculty and students in what then was loosely referred to as "the interaction of technology in the physical sciences with phenomena or processes that relate to the human being." In his charge to the committee, Dean Gordon S. Brown said, "... some are studying such problems as the behavior of blood flow in arteries; the freezing of human tissue in live subjects; the development of sensory aids; the response of the nervous system; and so forth."

The committee reported on March 5, 1965. The gist of their report was:
1. The level of interest and activity in both the research and educational
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aspects of Engineering and Living Systems (E.L.S.) is substantial and growing among faculty members of the School of Engineering and among graduate students.

2. At M.I.T. these activities should be known as Engineering and Living Systems — E.L.S.

3. The School of Engineering can fulfill its educational role best by encouraging a variety of training programs tailored to the needs and strengths of the individual rather than a single program that would emphasize only a limited common denominator aspect across an impossibly wide domain.

4. Extrapolating recent trends and assessing current plans, the following conservative estimate can be made: Within the engineering departments active in E.L.S., interest might grow to a level at which it would involve 10 to 20 per cent of faculty and students. This figure, subject to correction, applies basically to graduate education, though increased participation of undergraduate engineering students in biology might well enlarge this figure.

5. There appears to be a great need for new and novel programs for reconversion or reorientation education of practicing engineers and members of the medical professional in each other's area of specialization.

The existence of the School of Engineering committee on E.L.S., and the forum that its activities established, soon had tangible effect on the M.I.T. community. The scope and the effectiveness found within the working relationships already established by many M.I.T. professors with medical experts in the hospitals and medical schools in the Boston area was most impressive. The initial documentation of the inventory of subjects already being taught by M.I.T. faculty and the inventory of research projects showed that a new professional field was emerging. No single person or group dominated it, or had even spurred it. On the contrary, it appeared to have come about simply as a result of M.I.T.'s open-ended self-generative environment.

From this informal beginning in 1964, one event has followed another. To support our search for guidelines as to where M.I.T. as a whole should go in this area, the Commonwealth Fund sponsored a conference during the period June 13 to 23, 1967, at Brandegee House, the home of the American Academy of Arts and Sciences. Seventy-one participants, comprising faculty, research staff, medical department staff, and administration, attended from within the M.I.T. community. Fifty-four participants, drawn from other schools, hospitals, foundations and government, came from outside M.I.T.

Our evaluation of the situation following this ten-day conference was
that a great deal of further study and reflection was needed before we would understand it fully. We were impressed not only by the large amount of work already being pursued vigorously at the interface between the life and physical sciences, but also by the need for better understanding by the medical practitioner, the physical scientist, the life scientist and the engineer, of how knowledge and skill already available in a bordering field could be exploited to enrich his own field. The need for a large corps of people educated to a high level in a new mix of the life, physical, and engineering science disciplines was very apparent.

It was clear also at this time that no one could say whether M.I.T. could satisfy the aspirations of its faculty and students in these areas wholly from resources already in existence, or which might be readily acquired, or whether a major new addition, even to the extent of a medical facility, would be needed.

As these questions were being pursued, two noteworthy events took place. One event was the announcement on September 12, 1967, jointly by President Nathan M. Pusey of Harvard University and President Howard W. Johnson of M.I.T., establishing a Joint Liaison Committee of Engineering and Living Systems to permit the two institutions to join forces to explore the effective use of their complementary resources in the engineering, life, and health sciences toward the objective of a continuing improvement in our national health. The two institutions will seek opportunities for collaboration in basic and applied research, education, and medical care.

The second event was the establishment within the National Academy of Engineering (N.A.E.) of a committee on the interplay of engineering with biology and medicine under a contract with the Office of Program Planning of the National Institutes of Health. As stated by N.A.E., the broad purpose of the committee is to delineate clearly the characteristics and limitations of modern engineering and the means by which the national engineering capability can be directed effectively toward the fundamental and applied problems of concern to the National Institutes of Health.

In mid-November, 1967, Dr. John G. Truxal, Chairman of the N.A.E. committee, wrote to M.I.T. asking that the Institute submit a proposal to study the role that M.I.T. might appropriately play in meeting the objectives and needs of the national program. A substantial number of other schools received a similar request. Specifically, the N.A.E. invited M.I.T. to give its view of the role, extension or application of engineering concepts, theory, and technology in "(a) scientific inquiry into biological phenomena as a basis for advancing the understanding of
biological systems; (b) the development of instrumentation, materials, diagnostic and therapeutic devices, artificial organs, and other constructs relevant to the solution of major problems in the areas of biology and medicine; and (c) the development and further evolution of social systems and such microrepresentations of social systems as hospitals or related health service units."

By the early spring of 1968, M.I.T. and Harvard received a joint contract from the N.A.E. under this program. During the late spring and summer, scores of M.I.T. faculty collaborated with professors and doctors from the Harvard University medical establishment on the problems. A joint Harvard University-M.I.T. report, including an assessment of M.I.T.'s possible role in future activities, was submitted to the N.A.E. on September 30, 1968, where, together with reports from five other institutions, it is now being evaluated. Aspects of this work formed the subject of discussion at the Symposium on Engineering and Medicine conducted by the N.A.E. at its meeting in Washington on October 30 and 31, 1968.

As a result of our four years of deliberation, it is now abundantly clear that the students, faculty and administration of M.I.T. have been presented a challenge of enormous magnitude. There is a temptation to respond merely by accelerating the tempo of current activity without assessing the over-all problem of how a program such as we are discussing here can be efficiently and productively embedded into the complete matrix of people, facilities, and philosophies that are loosely referred to as Harvard University and M.I.T. Clearly, neither institution at the present time has uncommitted funds or facilities that represent even a small fraction of what is needed properly to pursue the optimum program. Merely to increase the tempo of what we are now doing would cause us to run ahead of our supply lines and would result in widespread frustration of creative people and increased turbulence in an already turbulent arena. New funds in the amount of millions of dollars, and new facilities are clearly needed. It is probable that a new organizational structure and possibly a new institutional entity will be required.

Concern for these matters is one of our central interests at the present time.

**IN VOLVEMENT IN URBAN AFFAIRS**

Of all the engineering professions, that of civil engineering has traditionally been the one most deeply involved in urban problems. But as the field of engineering has broadened, and as the way man lives and works has become more complex, all engineers, but civil engineers in
particular, have found increasing opportunities in the urban scene for the application of their talents.

To appreciate the problems our future engineering graduates will face, we only need to realize that one of the tasks facing society is the rebuilding of many of our major cities.

The future will demand improved facilities for transportation of people, food, and industrial goods. Air, rail, road, and water transport systems must change and be coordinated. Airports must be redesigned, relocated and multiplied in number. The future here is rich with opportunities in which technological and sociological problems interact and demand boldness, imagination, and a subtle blend of technological, cultural, religious, aesthetic, and recreational issues. Our concern must be with the totality of how man lives and makes his living.

The achievement of efficient management of the modern city is one of our most urgent problems. Cities continue to become more complex, the demands of their citizens for services proliferate, and the expectations of their citizens for higher standards of living increase.

The degree to which city decision makers have access to modern technology in areas such as the gathering of key management data, the keeping of records on the condition of capital facilities, and the itemization of assets, of tax revenues, or of revenue-producing activities, to name only a few, is woefully deficient. The instrumentation and measurement of many processes and the introduction of computer technology into city management are problems yet to be solved. The concept of a profession of city management has yet to emerge within our socio-economic system.

The doctrines evolved for the management of a business do not adapt easily to the management of a city. The profit motive that spurs business management to efficient practices is absent. For business and industry, both the product and client are clearly defined. The city, however, must furnish its citizens with a complex mixture of facilities and services. Doctrines that govern the attitudes of citizens establish a vague value system. Taxes are so unevenly distributed that a value-received criterion is difficult to establish within an urban environment. Every element in the process is highly interactive with many others, and attempts to make mathematical models of cities for the study of procedures or to test hypotheses have, for the most part, yielded oversimplified situations in which the principle of cause and effect is applied to the wrong variable, or without recognizing the impact of either feedback or side effects.

As we study the city and the manner in which it grows and compare what we see to the process by which a major business grows and is managed, the city emerges as a technologically deprived entity. Because the
technologist-client relationship within the city is so diffuse, it has been almost impossible to organize or finance research and development programs of critical size to study such seemingly mundane problems as the disposal of wastes, the amelioration of environmental pollution, the elimination of urban filth, or the development of low-cost housing. Clearly, society must find ways to evolve better social indicators to guide our attack on these problems and, subsequently, invent and develop the new institutions, such as government or private non-profit corporations, to develop the appropriate technologies and make their products accessible to cities as clients and consumers.

Since 1959, Harvard University and M.I.T. have sponsored a Joint Center for Urban Studies. This Center has worked closely with our Department of City and Regional Planning, which for 35 years has made important contributions to the study and design of cities. The activities of the Joint Center, however, have tended to be oriented more toward study and research in problem areas rather than toward action and tangible engagement in the solution of problems. Broadly speaking, the Center's dialogue with engineering at M.I.T. has been quite small.

But concern for these problems in the School of Engineering has been growing for several years. The number of projects under way within the Department of Civil Engineering at M.I.T. in which the faculty and students are engaged in actual projects with city bureaus or departments is increasing. There have been school-wide programs such as the Northeast Corridor High-Speed Ground Transportation Project (Project TRANSPORT), as reported in prior years. The studies pursued by student groups last year toward the economic development of the Boston Harbor form other examples. All these activities point to the fact that, increasingly, on-campus laboratory models of real-life problems will lack authenticity unless they constitute a part of a larger program that uses the city itself as the laboratory and major arena of involvement.

In recognition of the importance that the non-technical disciplines play in gaining an understanding of the urban problem, the Institute responded in early 1967 to an invitation from the Ford Foundation by establishing an ad hoc Faculty Committee on Urban Affairs. This M.I.T.-wide group was asked to assess our activities in the urban field and propose ways both to broaden and deepen the involvement of faculty and students.

In response to a proposal prepared by this ad hoc Committee, the Ford Foundation announced in November, 1967, a grant to M.I.T. for a period of three years to encourage and support a major program of education and research in urban affairs. This grant will involve teaching,
research and faculty development in the Schools of Architecture and City Planning, Engineering, Management, and Humanities and Social Science. It provides endowment for three professorships in urban affairs; it supports the establishment of an interdepartmental laboratory to be known as the Urban Systems Laboratory, it supports a program of fellowships in urban affairs and it makes it possible for M.I.T. to bring to the campus national leaders to lecture, to teach, or to participate in research.

Last January, former Mayor John F. Collins of Boston was appointed Visiting Professor of Urban Affairs in the Departments of Political Science and Civil Engineering, and in the Alfred P. Sloan School of Management. More recently, Dr. John W. Gardner, former Secretary of the Department of Health, Education, and Welfare, was appointed to the Germeshausen Professorship. In endowing this chair, it was Mr. Germeshausen's wish that the professorship be undesignated as to specific field but that the occupant be one who could support M.I.T.'s strong interests in combining humanitarian advance with technological progress. Dr. Gardner will be affiliated with the Urban Systems Laboratory.

One especially significant action following the award of the Ford Foundation grant was the establishment of an Urban Systems Laboratory (U.S.L.). This entity is both interdepartmental and multidisciplinary and aims to mobilize M.I.T.-wide resources. Its director is Professor Charles L. Miller, Head of our Department of Civil Engineering.

As Professor Miller explains in more detail in his report on the first half-year of operation of the Laboratory, U.S.L. is not a physical laboratory or a separate division of the Institute, but, rather, a community of people concerned with and active in the field of urban systems. U.S.L. is an open community. Its creation is a direct response to the recommendation of the ad hoc faculty committee on urban affairs which said:

The Institute has pioneered in the fields of operations research, information sciences, computer technology, and systems development. Strengths, resources, and interests in systems research and computer methods of problem solving exist in significant quality and quantity throughout the Institute. Extensive activity in systems analysis and information systems is under way in the Schools of Engineering, Management, Humanities and Social Science, and Architecture and Planning. The powerful problem-solving capabilities represented by these resources offer one of the Institute's greatest potentials for making significant contributions to the formulation and solution of the complex problems of the city.

In order that this Laboratory can proceed vigorously to develop a major area of interest, namely information systems, the decision was made to assign to the Laboratory primary management responsibility for the initial systems development of the IBM System/360, Model 67
computer which will be installed on the campus in August and which will be operated as an experimental facility, as opposed to a service facility. Extensive computer software developments are already available at M.I.T. and programs unique to the urban problem can be built upon them. Examples of existing software include DISCOURSE (Architecture and City Planning), ADMINS (Political Science), DYNAMO (Management), AED (Electronic Systems Laboratory) and ICES (Civil Engineering). The Model 67 will be operated under CP/67, a control program developed by the IBM Cambridge Scientific Center. Funds to support this work are being provided under a grant from IBM to M.I.T. for the development of our information processing activities.

During the summer of 1968 the M.I.T. Faculty conducted three summer studies in the urban systems area; two under support from the Department of Housing and Urban Development (HUD) and one under M.I.T. support. One study under the general direction of Professor Mason Haire, Professor of Management, explored the general topic “Matching Technology to Urban Affairs.” This study sought to explain why there is so little evidence of the use of sophisticated and modern technology in meeting urban needs. The study also explored the feasibility and the form of new social institutions or new educational programs that would improve on the present situation.

A second HUD-sponsored study, under the general direction of Professor Richard L. deNeufville of the Department of Civil Engineering, was designated “Urban Information Systems.” Specifically, it aimed to identify the data that would be relevant to the planning and design of urban management systems, to assess the magnitude of effort required and the kinds of analytic capability needed for a suitable data base, to encourage its development, to outline the technical machine programs necessary in specific areas such as assessment, welfare or police work, and to give guidelines for future work. Reports on both of these summer studies were submitted to HUD on September 30, 1968, and are presently being examined and assessed.

Under support furnished by M.I.T. from its Sloan Basic Research Fund, a third group, under the direction of Professor Wilson of the Department of Mechanical Engineering, examined the “Management of Solid Wastes.” This study proved especially productive in generating ideas that could be put into effect immediately. On October 16, 1968, certain of the findings were presented by Dr. Wilson and his colleagues to the mayors and selectmen of about 40 cities and towns in the greater Boston area. An editorial in the Boston Herald of October 17, 1968, appropriately sums up this work as follows:
Trash disposal was once an almost invisible problem, handled quietly (if not with great enthusiasm or efficiency) by homeowners, businesses, small contractors and a few municipal offices.

Only in the last few years, an M.I.T. study group has noted, have "the problems of increasing affluence, increasing population, the migration of people to the cities, and the impact of waste disposal on growing problems of air and water pollution . . . combined to demonstrate the inadequacies of our present institutions and methods."

Now, almost suddenly, we have realized that trash disposal costs the nation at least $3 billion a year, the volume of solid waste is increasing at an alarming rate, the prospects of keeping up with it are dim, and there might be a grain of truth in Lt. Gov. Sargent's warning that eastern Massachusetts will soon face the possibility of being buried by its own trash.

The report which M.I.T. released Wednesday on its summer study of the management of solid waste is a major step toward a rational solution of the problem. It will be the subject of future editorials.

One immediate benefit of the report should be to convince the communities involved to stop their squabbling over the plan for a regional incinerator serving Melrose and seven other towns. Fragmentation of resources has long been one of the major factors retarding the growth of a modern disposal system.

If seven communities cannot, in their common self interest, agree on the operation and control of a single incinerator, then hope for instituting the greater efficiencies of large-scale consolidations is dim indeed.

THE COMPUTER CONFERENCE IN WEST BERLIN

In 1964, under sponsorship of the Ford Foundation, M.I.T. and the Technical University of West Berlin (T.U.B.) began a program of cooperation through faculty exchange. Up to June 30, 1968, M.I.T. had received as guests 34 faculty and staff from T.U.B. representing such fields as management, economics, engineering and science. In turn, 35 members of the M.I.T. community have spent from a few weeks to as long as a year at T.U.B. exchanging ideas and insights in their professional fields as well as in institutional organization and the management of educational innovation.

During the year 1966-67, Dr. Karl Zander from T.U.B. was affiliated with our Electronic Systems Laboratory. In the course of his work, he recognized the widespread impact of the high-speed digital computer on academic life. Not only was he impressed with the power of the computer as an aid to teaching and research, but also as a strong unifying force for bringing together many faculty from a variety of disciplines to work together on problems of mutual concern.

In response to these impressions, Dr. Zander conceived the idea of a joint M.I.T.-T.U.B. conference devoted to "The Computer in the University." His enthusiasm was shared by both the M.I.T. and T.U.B communities and a conference took place at the Technical University in Berlin, from July 22 to August 2, 1968. Thirty members of the M.I.T. community, representing such diverse fields as administration, engineering,
management, science, music and architecture, joined with their colleagues from T.U.B. and other European universities to discuss the impact of the computer on all domains of campus life, its cost of operation, its penetration into the conduct of the teaching-learning process, its relation to the character of curriculum content, its role in research, the problems of its operation as an efficient service facility, and its impact on society.

Registration for the conference exceeded 1,200. Participants were drawn from more than 37 countries and included university students, faculty and staff, government officials and representatives of industry. Three evening sessions on The Computer in Social Science Research, in Music, and in Art were open to the general public. Simultaneous translation facilities were available for English and German.

A graphic display terminal and typewriter terminals were installed at T.U.B. and connected by a dial-up, transatlantic cable to the IBM 7094 computer at Project MAC in Cambridge, Massachusetts. Demonstrations of the time-sharing system CTSS and particular technical programs of interest to smaller groups of participants were presented outside of the formal conference.

During both the free hours and the extensive social program, there was ample opportunity for small discussion groups and technical meetings. This provided a means for the participants to obtain a deeper understanding of the many differences between the European educational system and our own educational philosophy at M.I.T. and strengthened the personal and professional ties between M.I.T. and T.U.B.

This conference represented probably the largest single international commitment undertaken by M.I.T. and also the largest conference presented by just two universities cooperating in an international program. The coverage of the conference by television, radio, newspapers and magazines was extensive.

We are deeply indebted to Professor Arthur T. Ippen and Professor Joseph Weizenbaum of M.I.T., who with Dr. Karl Zander and Dr. Rudolf Wille, the newly elected pro-rector of T.U.B., assisted Dr. Gundlach in Berlin, and comprised the organizing committee.

PERSONAL NOTES

This report of the School of Engineering is the last that will carry an introduction by Deans Gordon S. Brown and William W. Seifert. Effective November 1, 1968, Dr. Raymond L. Bisplinghoff becomes the Dean of Engineering. Dean Brown, who has served as Dean since 1959, asked to be relieved of administrative duties. He has been appointed to a new chair, the Dugald C. Jackson Professorship in Engineering.
Effective July 1, 1968, Assistant Dean William W. Seifert asked to be relieved of administrative duties to devote his full attention to teaching and research. In addition to returning to his position as Professor in Electrical Engineering, he has been appointed Professor of Engineering in the Department of Civil Engineering. Professor Seifert is succeeded by Robert H. Scott, who was appointed Assistant Dean for Administration on July 1, 1968.

Effective November 1, 1968, Professor Rene Miller, H. N. Slater Professor of Flight Transportation in the Department of Aeronautics and Astronautics, succeeded Dr. Bisplinghoff as head of the Department of Aeronautics and Astronautics.

Effective December 8, 1967, Professor Paul E. Gray of the Department of Electrical Engineering was appointed Assistant Provost. In this position he will develop and coordinate the undergraduate curriculum and seek to improve teaching methods and facilities for undergraduate instruction.

Professor Gray has also been appointed Class of 1922 Professor to succeed Professor John Wulff of the Department of Metallurgy and Materials Science, who retired on June 30, 1968. This professorship was established at the 40th reunion of the Class of 1922 with the stipulation that the occupant of the chair devote at least 50 per cent of his time to teaching or the preparation therefor.

Professor Robert L. Halfman of the Department of Aeronautics and Astronautics was appointed the M.I.T. Representative on the Steering Committee of the Kanpur Consortium. Under support from the Agency for International Development, the Consortium of American Universities is assisting the government of India in developing the Institute of Technology at Kanpur.

Dr. Harold L. Hazen has been appointed Foreign Study Advisor following his retirement as Dean of the Graduate School on July 1, 1967. Dr. Hazen succeeds Professor Emeritus John T. Norton, who served in this position for the past four years. As a consultant on engineering education in Japan, Turkey, Lebanon, Iceland, Brazil, and Saudi Arabia, Dr. Hazen brings wide experience to his new position.

During the year Professor Morris Cohen, Ford Professor of Materials Science and Engineering in the Department of Metallurgy and Materials Science, was elected to the National Academy of Sciences. Professor Miller, H. N. Slater Professor of Flight Transportation, and Professor Robert C. Seamans Jr., Visiting Jerome Clark Hunsaker Professor, both in the Department of Aeronautics and Astronautics, were elected to the National Academy of Engineering.
Professor Hoyt C. Hottel of the Department of Chemical Engineering received the 1967 Founders Award of the American Institute of Chemical Engineers on November 27, 1967, at the Sixtieth Annual Meeting of the A.I.Ch.E. This award recognizes chemical engineers who have contributed to the engineering profession through their outstanding service and achievements.

Institute Professor Emeritus C. Richard Soderberg of the Department of Mechanical Engineering was awarded the De Laval Medal by the Royal Academy of Engineering Sciences in Sweden at the Academy in Stockholm on May 8, 1968. This medal was awarded in celebration of the 75th anniversary of the formation of the industries initiated by Gustaf De Laval. Professor Soderberg was also made Commander of the Royal Order of the North Star by the King of Sweden on May 7. The award was presented by the Governor of the Province of Ostergotland.

Professor Egon Orowan, also of the Department of Mechanical Engineering, received the 1968 Carl Friedrich Gauss Medal from the Braunschweigische Wissenschaftliche Gesellschaft for distinguished contributions to the physics of strength and plasticity.

Professor Norman C. Rasmussen of the Department of Nuclear Engineering was awarded a Doctor of Science, honoris causa, by Gettysburg College in June, 1968; and Gordon S. Brown, Dean of the School of Engineering, was awarded a Doctor of Engineering, honoris causa, by Stevens Institute of Technology in June, 1968.

In February of 1968, Professor Norman C. Dahl of the Department of Mechanical Engineering resigned to become the Deputy Representative of the Ford Foundation in India. Professor Dahl had been on the staff at M.I.T. since 1948.

Five senior members of our faculty retired during the 1967-68 academic year. They are Harold E. Edgerton, Institute Professor and Professor of Electrical Measurements, widely recognized for his development of high-speed photography; Hoyt C. Hottel, Carbon P. Dubbs Professor of Chemical Engineering, known internationally as an authority on combustion; Egon Orowan, Professor of Mechanical Engineering and a distinguished authority on the physics of metals and behavior of solids; Edward S. Taylor, Professor of Flight Propulsion, who has served as Director of the Gas Turbine Laboratory since 1946 and is known as an authority on engine vibration and the developer of the dynamic vibration absorber for aircraft engines; and John Wulff, Class of 1922 Professor of Metallurgy, who has been largely responsible for the development of the undergraduate subjects concerning the structure and science of metals.
DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

DEPARTMENT OF AERONAUTICS
AND ASTRONAUTICS

The present report has been prepared in an environment of continuing interest in engineering education in the fields of aeronautics and astronautics. The steady growth of scheduled air transportation and general aviation is producing a resurgence of interest in aeronautical engineering education and civil aeronautics research and development. A question frequently asked the Department is whether the historic upward trends in the growth of civil aviation can be expected to continue through another decade in spite of potential technical and social restrictions. The Department faculty is strong in its belief that, in a favorable economic climate, these upward trends can be continued and even accelerated if a carefully planned program of research and development aimed specifically at the civil air transportation system is carried out. In the field of astronautics, the Department faculty sees a period of reduced growth in interest over the near term but steady growth over the long term. The over-all feeling of the Department faculty is one of optimism for the future of education and research in aeronautics and astronautics at M.I.T.

THE UNDERGRADUATE SCHOOL

Enrollments in the undergraduate school fell off somewhat. During the fall term there were 68 sophomores enrolled, compared to 78 juniors and 81 seniors. Bachelor's degrees awarded during the year numbered 62.

After a rearrangement of the Department's cooperative course directed toward lengthening the time spent at the cooperating company, only two students entered the program. Though this response is disappointing, the Department believes that the course is educationally desirable and expects increased participation next year.

Elective subjects and seminars were presented to about 150 freshmen during the year. The largest groups were those in Aerospace Engineering taught by a group of faculty members, and in Flight Vehicles taught by Professor Otto C. Koppen. Freshman seminars were also offered by Professors Joseph Bicknell, Secor D. Browne, Morton Finston, Robert K. Mueller and Sheila E. Widnall.

Since the Department's beginnings, its undergraduates have been taught thermodynamics by the Department of Mechanical Engineering. With the increased size of the Fluid Mechanics Division of instruction has come interest and competence in thermodynamics. Over a period of some years, faculty members have joined mechanical engineering faculty in teaching Course xvi students. This year, Professor Harold Y. Wach-
man was in charge of the three sections of Thermodynamics and Statistical Mechanics, 16.001J, which are composed solely of Course xvi students. At the end of this year, the Department will take over completely the teaching of thermodynamics to Aeronautics and Astronautics students with Professors Wachman, James P. Moran and Albert Solbes carrying the teaching responsibilities. The Department's debt to the many mechanical engineering faculty members who have labored over the years to present this difficult subject is acknowledged with thanks.

The past year saw an unexpected increase in the number and quality of students taking the senior Space Systems Engineering subject, 16.73. The faculty feel that this has been one of the best group of students we have yet seen in 16.73, with a high degree of interest and participation evident. Currently, we are managing to attract some of our best students to this area of applied engineering, probably due to a concerted effort by the entire staff to emphasize the importance of application in addition to an understanding of the basic scientific principles of engineering.

Experimental Projects, 16.62, continues as the cornerstone of undergraduate laboratory instruction. During the past year, five faculty members, one representing each teaching area, took part in the supervision of 16.62. Enrollment was 28 students in the fall term and 42 in the spring term.

The weekly cider hours for undergraduate students again proved to be worthwhile opportunities for students and staff to meet informally.

The Admiral Luis de Florez awards for "ingenuity and original thinking" were given to George W. Diemer III, Gordon K. Mandell, Peter S. Maybeck, James S. Rhodes Jr., Carson M. Strong, and Michael Weinreich.

The awards were made on the basis of experimental projects and systems analysis and design.

James Means Memorial Prizes were awarded to Thomas J. Lang, Peter S. Maybeck, and Stuart J. Weidenschilling.

The awards were made on the basis of superior system analysis and design work.

The Henry Webb Salisbury award for outstanding academic performance in the Department of Aeronautics and Astronautics was awarded to Wayne R. Johnson.

THE GRADUATE SCHOOL

During the year graduate enrollment in the Department suffered a slight decrease. It was 169 plus 83 special students in the first term and 150 plus 56 special students in the second term, in spite of the fact that appli-
cations for admission were higher in 1967 and in 1968 than in previous years. It appears that we are witnessing a more thorough attempt on the part of prospective students to make multiple applications and to seek the best academic and financial arrangement among leading aerospace departments. Our most active rivals have been Stanford, Princeton, Cornell, and Michigan.

During the year graduate students in the Department have been awarded 23 doctorates, six engineering degrees and 54 Master's degrees. The number of doctorates earned, in particular, is maintaining a slight upward trend. The present decrease in enrollment has not yet been reflected there.

The next academic year will present particular difficulties. The recently promulgated Selective Service policy is sure to reduce the number of American graduate students entering the Department, although it is too early to predict to what extent. At the same time, recent Federal budget cutbacks and the obvious threat of further cutbacks have made the directors of the various laboratories within the Department more cautious in offering research assistantships. It is clearly more difficult to keep in balance the supply and demand for assistantships in this slowly shrinking situation than it would be in a period of expansion. As a result, it has not been possible to place all applicants in the fields in which they expressed their prime interest. There is an increasing proportion of applications from abroad, particularly from India and Taiwan, and a reluctance on the part of laboratory directors to offer scarce assistantships to such applicants, sight unseen. The fact that the Instrumentation Laboratory is generally out of bounds for such applicants puts a heavy burden of such requests on the other laboratories in the Department. The pressure appears particularly severe in the Aeroelastic and Structures Laboratory.

Leadership in the Department's graduate program will shift, beginning in the fall term of 1968. Professor Leon Trilling has held the post of Graduate School Officer, Chairman of the Graduate School Committee of the Department, and Departmental Representative on the Graduate School Policy Committee of the Institute since 1959. His performance in this difficult post has been an inspiration to the Department. Professor Judson R. Baron will assume these duties in the fall, and Professor Trilling will undertake the duties of Professor in Charge of the Mechanics and Physics of Fluids Division of Instruction.

Since Professor Marten T. Landahl's departure, Professor H. Philip Whitaker has taken over the chairmanship of the Department Doctoral Committee, Professor James E. McCune acting as Vice Chairman. We
are planning to operate on the basis of two years of service for the Chairman, the chairmanship rotating between divisions of the Department. The new Vice Chairman is Professor Theodore H. H. Pian. Professor Jacob L. Meiry will follow him. We are still experimenting with our qualifying examination, which is not wholly satisfactory, although it has been refined this year. We have also systematized and improved the handling of the thesis presentation by requiring each candidate to present his thesis at an open seminar and to submit a brief paper in which his main new findings are described. This paper is circulated to the faculty before the seminar.

The Instrumentation doctoral program continues to be healthy, with 30 students and 22 faculty participating. Eight degrees (two Doctor of Philosophy and six Doctor of Science) were awarded in this program during the past year. The program has had one general take-home examination, plus orals, with competence in applied mathematics, applied physics and control systems required of all students. Each student also selects his primary professional area in Instrumentation, Guidance, and Control as well as a secondary professional area for the remainder of the examination. With this specified breadth, no formal minor is required. This fall, in order to examine students earlier in the required fields and to aid in admission determination for students from other colleges, a closed-book qualifying examination in mathematics, physics, and controls will be instituted. The primary and secondary professional examinations will be taken later at the Advisory Committee's discretion. With these changes, the administrative pattern of the Instrumentation doctoral program becomes closer in form to that of the regular Department program.

THE FACULTY

Promotions among Department faculty members included Eugene E. Covert, James E. McCune and Walter McKay to Professor, and E. Eugene Larrabee, James E. Potter and Robert W. Simpson to Associate Professor.

Dr. John C. Evvard, Associate Director of the Lewis Research Center, National Aeronautics and Space Administration (NASA), served as the Jerome C. Hunsaker Professor during the past year. Professor Evvard's lectures on propulsion and power systems and his counsel on the future direction of these activities in the Department were very valuable for both students and staff. The Department will be exceptionally fortunate during the coming year to have Dr. Robert C. Seamans as the 1968-69 Jerome C. Hunsaker Professor.
Professor Rudolf L. Wille of the Technical University of Berlin spent the first term of the year just ended as Visiting Professor of Aeronautics and Astronautics. Professor Wille proved to be a very stimulating colleague and his visit was a most profitable experience for the students and faculty of the Department.

Professor Robert L. Halfman, who has been on leave during the past two years in Kanpur, India, will return in September to resume his duties as Deputy Head of the Department. Professor Edward S. Taylor, a member of the M.I.T. Faculty since 1927, retired at the end of the year. Professor Taylor will continue his affiliation with the Department as Professor of Flight Propulsion, Emeritus, and Senior Lecturer.

Professor James W. Mar was on leave from the Department to assume duties as the first W. W. Clyde Visiting Professor in the College of Engineering of the University of Utah during the spring quarter of that institution. Professor Myron A. Hoffman left the Department at the end of the year to accept an appointment on the faculty of the University of California at Davis.

Appointments for the coming year include Heinrich Hertel of the Technical University of Berlin, Michael N. Kogan of the Academy of Sciences of the U.S.S.R., and Ernst A. Steinhoff of the Air Force, all as Visiting Professors of Aeronautics and Astronautics. Michael Judd of the University of Southampton has been appointed Visiting Associate Professor of Aeronautics and Astronautics. Shaoul Ezekiel, David A. Oliver and David B. Stickler will all join the Department at the beginning of the coming year as Assistant Professors of Aeronautics and Astronautics.

**SPECIAL LECTURES AND SEMINARS**

The 11th Minta Martin Lecture was presented on February 27, 1968, by Professor Evvard, the Jerome C. Hunsaker Professor for 1967-1968. The lecture, entitled “A Philosophy of Reexamination,” was very well received by a large audience in the Little Theatre, Kresge Auditorium. Professor Evvard repeated his lecture at the University of Maryland and at the Lewis Research Center in Cleveland, Ohio.

Dr. Arthur E. Raymond presented the ninth Lester D. Gardner Lecture on May 2, 1968. Dr. Raymond’s subject was “Air Transport History and a Glimpse into the Future.” The lecture was well attended and enthusiastically received by students, faculty, staff and friends from outside M.I.T.

Under the leadership of Professor Mar, the Department’s Seminar Series sponsored 25 lectures by leaders in the various fields of aeronautics and astronautics. Five speakers were from outside the U.S.A.,
one was from the Department and the balance were from industrial and governmental establishments and from universities throughout the United States. The following list summarizes the speakers and their topics in the 1967-68 seminar series:

**DR. CHARLES BARTLETT**, Smithsonian Institution, Astrophysical Observatory
"Ionizing Shock Waves in Stellar Atmospheres"

**SIDNEY GREEN**, Research and Development Laboratory, General Motors Corporation
"Recent Investigations at General Motors on the High Strain Rate Behavior of Materials"

**PROFESSOR RUDOLF L. WILLE**, Technical University of Berlin (Visiting Professor in the Department)
"Subsonic Near-Wake Flow Behind Obstacles of Finite Length Such as Ship’s Funnels"

**PROFESSOR E. STIEFEL**, Swiss Federal Institute of Technology
"Three-Dimensional Regularization"

**MARTIN R. FINK**, United Aircraft Research Laboratories
"Optimum Bodies of Revolution at Low Hypersonic Speeds"

**PROFESSOR Y. C. FUNG**, University of California
"Mechanics — An Approach to Bioengineering"

**DR. JOHN F. MC CARTHY**, North American Rockwell Corporation
"The APOLLO IV Mission"

**PROFESSOR HOLT ASHLEY**, Stanford University
"Expanding the Consciousness of the Aeroelastician"

**DR. MORTON CAMAC**, AVCO Everett Research Laboratory
"Shock Structures and General Flow Field Measurements Using Electron Beam Techniques"

**DR. ROBERT CENTER**, AVCO Everett Research Laboratory
"Measurements of Shock Wave Structure in Helium and Argon Mixtures"

**MR. HARLETH G. WILEY**, NASA Langley Research Center
"The Significance of Non-Linear Stability Derivatives to the Flight Characteristics of Current Aircraft"

**PROFESSOR LUCIEN A. SCHMIT**, Case Institute of Technology
"A Structural Synthesis Capability for Integrally Stiffened Cylindrical Shells"

**DR. ROBERT CENTER**, AVCO Everett Research Laboratory
"Measurements of Shock Wave Structure in Helium and Argon Mixtures"
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“Feedback Control Aspects of Orientation to Light and Gravity in Animals”
DR. C. STARK DRAPER, Instrumentation Laboratory, M.I.T.

“Flight Systems and Modern Technology”
PROFESSOR GEORGE L. MELLOR, Princeton University

PROFESSOR F. K. MOORE, Cornell University

“Self-Confined Rotational Flows”
DAVID V. STALLARD, Raytheon Company

“Classical and Modern Guidance of Homing Interceptor Missiles”
PROFESSOR FRANK E. MARBLE, California Institute of Technology

“A Problem in the Dynamics of Gas-Particle Mixtures”
ROBERT HORONJEFF, University of California

“Analyses of Passenger and Baggage Flows in Terminal Buildings”
PROFESSOR ROBERT C. SEAMANS JR., Visiting Professor in the Department of Aeronautics and Astronautics, M.I.T.

“Returns from Aeronautical and Space Exploration”
DR. RICHARD HEAD, NASA Electronics Research Center

“Possible Solar Responses to Variable Planetary Influences”
PROFESSOR EDWARD ZUKOSKI, California Institute of Technology

“Jet Interaction with a Turbulent Boundary Layer”
S. BUTLER, Bath University of Technology

“Long Life Evaluated Temperature Problems of the Supersonic Transport Structures”
BRIAN LAUNDER, Imperial College of Science and Technology

“On the Prediction of Laminarization”

Professor Browne again organized a series of seminars dealing with the varied problems of flight transportation. They were attended by an audience drawn from the Institute and outside. The following speakers and topics were included in these seminars during the past year:

JOHN BORGER, Pan American World Airways
“Selection of Aircraft”

JOHN R. WILEY, Port of New York Authority
“Problems of Future Airports”

ROBERT SHANK, Airborne Instrument Laboratories
“Present and Future Air Traffic Control”

STUART G. TIPTON, Air Transport Association
“International Airline Operations”
THE DIVISIONS OF INSTRUCTION

The activities during the year in the five divisions of instruction of the Department are described in the sections which follow:

AERONAUTICAL AND ASTRONAUTICAL SYSTEMS

The Aeronautical and Astronautical Systems Division under Professor Rene H. Miller includes the following faculty members: Frank K. Bentley, Joseph Bicknell, Raymond L. Bisplinghoff, Secor D. Browne, Norman D. Ham, Jack L. Kerrebrock, Otto C. Koppen, E. Eugene Larrabee, Yao T. Li, Paul E. Sandorff, Robert W. Simpson, Edward S. Taylor, and H. Philip Whitaker.

Interest in flight transportation was high; 32 students registered this year in 16.751 compared to 26 last year and 23 the previous year. A new graduate subject entitled Flight Transportation Operational Analysis was offered by Professor Robert W. Simpson as a follow-on to 16.751J and was well attended with an enrollment of 18 students. Arrangements were made so that the students did their homework and term assignments on the computer, using programs developed in the Flight Transportation Laboratory. Both subjects generated a great deal of thesis interest and four doctoral theses were under way during the year in the area of flight transportation.

As in the past several years, the graduate elective subjects 16.74 and 16.362J were combined to form a preliminary engineering design exercise of a complex aerospace vehicle system. This group is customarily presented as a project study, the class being organized into technical groups, each of which is held responsible for a major subsystem. As is the case for a real project in industry, only the over-all problem is stated with any clarity; the detailed technical problems in any one area of specialty are determined by the form that particular subsystem takes in the final solution and the compromises it must make with the other subsystems.
Some 26 students registered this year, indicating a growing recognition among the student body of the systems design exercise as a unique educational experience. Two were graduate students from the Department of Nuclear Engineering; the remainder were Course XVI graduate students and fourth-year men. The problem this year concerned the design of a space probe to the outer planets and near interstellar space. With characteristic maturity, the class decided that such a technical development logically could be only part of a long-range national space program, and proceeded to outline objectives extending through 1980. They concentrated their efforts on a low-cost precursor vehicle, which would gather engineering and environmental data necessary for the design of later, more advanced vehicles.

Professor Sandorff was in charge of the subjects and was supported by Professors Li and Hoffman and Dr. Robert G. Stern. Lectures on special topics were presented by Professor Bernard F. Burke of the Department of Physics, Professor Robert S. Kennedy of the Department of Electrical Engineering, Richard H. Baker of the Department of Electrical Engineering, and Dr. Donald C. Fraser and Dr. William J. Beaton of the M.I.T. Instrumentation Laboratory. Special guest lecturers included Dr. Fred Whipple, Director of the Smithsonian Astrophysical Observatory; Dr. James Wilson of NASA Jet Propulsion Laboratory; Dr. John F. McCarthy of North American Rockwell Corporation; Dr. Maxwell Hunter and Dr. William W. Kellogg of Lockheed Missiles and Space Company. As in previous years, a high point for the students of Advanced Space Systems Engineering was a visit to Cape Kennedy on April 18. The students were guests of the U.S. Air Force on this trip.

The Department continued to draw on industry participation in teaching systems engineering subjects, a practice which has been welcomed by both students and industry and which it is intended to continue and amplify whenever possible.

STRUCTURES, MATERIALS AND AEROELASTICITY

The Division of Structures, Materials and Aeroelasticity, under the leadership of Professor Mar, includes the following faculty members: Raymond L. Bisplinghoff, Louis L. Bucciarelli, John Dugundji, Theodore H. H. Pian, Paul E. Sandorff, Pin Tong, Sheila E. Widnall, and Emmett A. Witmer.

During the past year there was a significant increase in the number of students attracted to the upper-level elective subjects in structures, materials and aeroelasticity. This is evidently due partly to a resurgence of interest in these fields but also to the enthusiasm which is generated
by the required undergraduate subject, 16.20, and the manner in which it is taught, employing frequent meetings of small recitation and tutorial groups in addition to the lectures.

Subject material on finite element methods in solid mechanics was expanded from a term to a full-year program under the supervision of Professor Pian. The first term was devoted to derivation of the variational principles, some of which are developed specifically for finite element methods of solid continua. The second term extended these principles to the analysis of plane elasticity, and plates and shells using various types of finite elements. Thermalelastic, elastic-plastic, creep and elastic stability problems were included in the second-term work.

A one-day Industrial Liaison Symposium, entitled "Static and Dynamic Analysis of Aerospace Structures," was held by the Department at the Statler-Hilton Hotel in Los Angeles on March 28, 1968, under the direction of Professor Mar. More than 120 people were in attendance.

Professor Mar and his colleagues also organized and hosted under Office of Naval Research (ONR) sponsorship an International Symposium on Structures Technology for Large Radio and Radar Telescope Systems. The symposium, held from October 18 to 20, 1967, at M.I.T., attracted more than 170 people with representation from six foreign countries.

A Special Summer program on Finite Element Methods in Solid Mechanics under the direction of Professor Pian and Professor Jerome J. Connor of the Department of Civil Engineering was held from June 24 to 28. Fifteen general lectures were given, seven by members in each department and one by a visiting lecturer. The total attendance was 180, a record for Summer Session Programs at M.I.T. The composition of the attendees included about 60 faculty members from universities in 25 states and Canada and Mexico.

MECHANICS AND PHYSICS OF FLUIDS


During the year approximately 15 per cent of the Department's regular graduate students indicated specialized interests in fluid mechanics. Ten of these students (42 per cent) have qualified for the doctoral program by passing the preliminary examination.
DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

A non-credit graduate student seminar in Mechanics and Physics of Fluids was held weekly during the spring term. The seminar has allowed a variety of research topics to be brought to the attention of a large group of students and simultaneously forces the students to explain and defend the purpose and direction of their investigations prior to the official thesis presentation.

The majority of the Division's staff is now located in the Center for Space Research, adjacent to both the Fluid Dynamics Laboratory and at least a portion of their Research Assistants.

INSTRUMENTATION, CONTROL AND GUIDANCE


Professor Vander Velde made major revisions during the year in Applied Optimal Control, 16.39. This subject, which has now been given twice, has been well received, not only because it is new but because the subject matter is of considerable interest in current research. Thirty-one students were registered for credit, more than half of which came from other departments, principally Electrical and Mechanical Engineering.

The Automatic Control System Laboratory, 16.33, under Professor Meiry, has grown steadily in attendance during the past three years and in the fall of 1967 drew 13 students. Professor Meiry continues to broaden the scope of the subject and to modernize its equipment, especially in the areas of guidance navigation.

A new subject, Life Support and Human Performance in Manned Systems, 16.43J, was formally offered for the first term under the direction of Professor Young and Professor Thomas B. Sheridan of the Department of Mechanical Engineering. All students in 16.43J were required to perform a team project including extensive reading and a meaningful experiment. The experience of actually digging into a life support or manual control problem is sufficient to overcome the "discipline barrier" for the students. Some of the lectures were given by specialists from other institutions, including the Harvard School of Public Health and the Army Natick Laboratories.
Professor Vander Velde, in collaboration with Dr. Arthur Gelb, completed a new book during the year entitled *Multiple Input Describing Functions and Nonlinear Systems Design*. During the six years the book has been in preparation the highlights of its contents have been taught in Principles of Instrumentation and Control, 16.32.

**PROPELION AND POWER**

The Propulsion and Power Division of Instruction, under the leadership of Professor Taylor, includes the following faculty members: Myron A. Hoffman, Jack L. Kerrebrock, W. Stephen Lewellen, James E. McCune, and Albert Solbes.

The subjects in Propulsion and Power taught during the past year, the names of the responsible staff members, and approximate number of students were as follows:

**Fall Term**

- 16.54 Airbreathing Engines — Kerrebrock 25
- 16.60 Ionized Gases — Solbes 8
- 16.561 Astronautical Propulsion — Lewellen 21

**Spring Term**

- 16.53 Rocket Propulsion — Lewellen 47
- 16.562 Astronautical Propulsion — Kerrebrock, Hoffman, Solbes 15
- 16.58J Advanced Topics in Plasma Kinetic Theory — McCune, Tam 20

In addition to these propulsion subjects, the staff of the Propulsion and Power Division participated in several others. Professor Hoffman taught part of Space Systems Engineering, 16.73. Professor Kerrebrock gave the propulsion lectures in Aerospace Engineering, 16.82. Professors McCune and Tam taught Gasdynamics, 16.03, and part of Topics in Fluid Mechanics, 16.031. Professor Solbes taught one section of Thermodynamics and Statistical Mechanics, 16.001J.

Although the Propulsion and Power Division will lose the services of Professor Taylor, Dr. Evvard, the Visiting Hunsaker Professor for 1967-68, and Professor Hoffman, it will gain two new staff members. Dr. David B. Stickler, who received his Sc.D. degree from M.I.T. in June, 1968, and Dr. David A. Oliver, now on the staff at the University of Santa Clara, will join the staff in September as Assistant Professors. Dr. Stickler will devote his attention to chemical rocket propulsion and Dr. Oliver to space power.

Professor Kerrebrock will assume the duties previously held by Professor Taylor as Professor in charge of the Propulsion and Power Division of Instruction.
THE RESEARCH LABORATORIES

The Department is organized for research into two divisions, the Aerospace Division and the Instrumentation Division. The Aerospace Research Division includes the Fluid Dynamics Research Laboratory, the Aerophysics Research Laboratory, the Aeroelastic and Structures Research Laboratory, the Wright Brothers Wind Tunnel Facility, the Space Propulsion Laboratory, the Experimental Astronomy Laboratory, the Man-Vehicle Control Laboratory, the Gas Turbine Laboratory, the Flight Transportation Laboratory, the Plasma Physics and Space Sciences Laboratory, and various facilities used for individual research by faculty members. The Instrumentation Division or Instrumentation Laboratory includes the guidance systems section, the guidance component section, and the guidance test facilities sections.

The Aerospace Research Division has equipment for research in all regions of flight from hovering to interplanetary. The Instrumentation Division pioneers in the development of control and guidance equipment for aircraft, missiles and space vehicles. Inertial guidance receives special attention, and the Instrumentation Laboratory is equipped with advanced facilities for research on all phases of control and guidance.

FLUID DYNAMICS RESEARCH LABORATORY

The Fluid Dynamics Research Laboratory represents a confederation of the interests of Professors Trilling, Moran, Wachman and Widnall. The Laboratory is a somewhat informal group supporting the work of faculty members and graduate students with no D.S.R. (Division of Sponsored Research) personnel.

The main activity in the Fluid Dynamics Research Laboratory has been in the field of low-density gas dynamics and gas surface interaction. Part of that research is analytical and has continued apace. Part is experimental, and it suffered a hiatus in the winter when the facilities were moved from the Aerophysics Laboratory to the Center for Space Research. The Laboratory is now completely reestablished in excellent quarters, with a good equipment base.

During the past year the research of the Laboratory, which is entirely carried out by faculty and students, has led to one completed doctoral thesis. Two more doctoral theses are in progress. Five Master's theses have been completed.

The fundamental task to which members of the Laboratory staff have addressed themselves is to gain a better understanding of the following problem: Given a flux of gas molecules at a given speed which approach a specified solid surface in a given physical state from a given direction,
what is the probability that they will be re-emitted from the surface at another speed, in a given state and direction?

Theoretical analysis of the problem involves three components: The distribution of the incoming flux, a proper model for the surface, and the physical interaction mechanism. All three are receiving some attention. The first is approached as a problem in the classical kinetic theory of gases, namely the analysis of the Knudsen layer in the neighborhood of a solid surface.

The second problem involving the nature of the surface is being studied on a number of levels. In particular, a simple model of an epitaxially growing surface may be constructed by a Monte Carlo method under the assumption that the probability of an incoming molecule coming to rest at a given site depends on the energy associated with that particular site as a result of its geometrical configuration.

The main theoretical effort of the Laboratory group has been devoted to the details of the interaction of individual gas molecules with ideal clean plane solid surfaces. A series of classical interaction models were constructed. The first model was a three-dimensional cubic lattice model of cold (or thermally uncoupled) metal and compared the energy transferred by the normal and tangential components of velocity. That original model has been the basis of several simplified and generalized calculations.

A further generalization consists in considering the solid as a continuous elastic medium under the action of a surface force the time history of which depends on the molecular interaction potential and the gas particle trajectory. Yet another extension of the same basic scheme is to the study of surfaces with chemisorbed monolayers.

The final application of the simple linear classical model is to the accommodation of diatomic molecules on solid surfaces. The essential factor here is the change in angular momentum of the gas molecules due to the fact that one of their atoms enters the surface interaction potential at a different velocity than the other.

Although the lattice model appears to provide a fruitful approach to energy interaction prediction and correlation, Professor Wachman and Dr. Frank O. Goodman have also prepared an interpolation model that accounts for a fraction of gas molecules being trapped on the surface. In order to analyze transfer, a different model appears necessary to correlate the diffuse lobular re-emission, diffraction and other experiments which are becoming readily available from many laboratories.

Recent analysis of molecular beam measurements indicates the probability that surface waviness on the atomic scale is in fact responsible
for the skin friction of gases on clean surfaces at high temperature. More detailed studies which include account of measurements of scattering out of the principal plane and the effect of lateral bonding heterogeneity in the presence of adsorbed layers should clarify the value of the present model.

**THE AEROPHYSICS LABORATORY**

The Aerophysics Laboratory, under the direction of Professor Finston with the assistance of Professors Baron and Covert, continued research activities in the general areas listed below:

1. Electromagnetic means of adding heat and directed velocity to a gas
2. Basic wake research using magnetic suspension systems
3. Antenna breakdown studies in the wind tunnel utilizing plasma simulation
4. Design of magnetic balance systems for hypersonic tunnels
5. Research in high mass transfer from surfaces
6. Radiation gas dynamic studies

New work was begun in the following areas:

1. Basic studies of hydrophone cable oscillations
2. Dynamic stability studies utilizing the magnetic suspension system
3. Experimental wind tunnel simulation of gust loads at supersonic speeds
4. Studies of store separation problems

Dr. Charles W. Haldeman, appointed Research Associate in the Department of Aeronautics and Astronautics last year, played a strong role in the direction of Laboratory activities during the year.

The level of funding last year remained essentially the same as it has been for the past few years and will remain about the same during the coming year according to present indications. Because of the increased cost of operating the Laboratory, the net result of an even level of support is a steady decrease in work accomplished. The same situation exists among several of the departmental laboratories.

**AEROELASTIC AND STRUCTURES RESEARCH LABORATORY**

The research activities of the Aeroelastic and Structures Research Laboratory have continued in the pattern of previous years under the leadership of Professor Witmer and with the active participation of Professors Dugundji, Ham, Mar, Miller, Pian and Widnall on contracts and grants from the Federal government. The work concerns unsteady aerodynamics and vibrations of helicopter rotors, non-linear and parametric vibra-
tions, static and dynamic elastic and elastic-plastic analyses of simple and complex structures using both finite-difference and discrete-element methods, buckling of shells and space-frame radomes, the mechanical behavior of metallic composites, and the development of blast loads and blast effects testing techniques.

Much effort has been invested in the Laboratory's Air Force project, devoted largely to developing discrete-element methods for the static structural analysis of re-entry type vehicle structures. Many structural features — single-layer shells, soft-bonded double-layer shells, core stiffening, cutouts, isotropicity and orthotropicity, elastic and elastic-plastic behavior, and thermal effects — are being included systematically. Two powerful new computer programs, SABOR 4 and SABOR 5, for the linear-elastic static analysis of shells of revolution, have been completed and will receive wide distribution shortly.

For the Picatinny Arsenal, the Laboratory has developed an analysis and computer program for the large deflection elastic-plastic analysis of highly heated and transiently loaded multilayer rings. Also, studies are nearing completion of the comparative features and feasibility of two discrete-element approaches for analyzing asymmetrical shells (as opposed to true shells of revolution).

For the New England Radio Astronomy Observatory Committee, the Laboratory constructed and static-tested a segment of a well defined space-frame radome model to produce reliable buckling data for such types of structures. Both local and general instability were produced. These data are intended to be used to check and validate maximum-load-buckling prediction methods for space-frame radome type structures. This experimental effort has been very successful and has now been fully documented.

The Laboratory has also been assisting the Air Force Weapons Laboratory in exploring the feasibility of using rocket-propelled sleds together with HE detonation in air and in freon-filled expendable shock tubes for re-entry vehicle blast loading and effects testing.

A basic study of rotor airloads is continuing under the supervision of Professor Miller with increasing emphasis on the problems of noise generation methods for alleviating the vibration in a helicopter by means of corrective control inputs. A new contract received from NASA will permit a more basic study of the vortex core structure and its interaction with the lifting blade. Work is continuing on the aerodynamics of a rotor blade beyond stall and on an improved method for determining the airload distribution on the blade in the presence of a deforming wake. Tests in the wind tunnel using flow visualization techniques have
been completed and have provided substantiation of the theoretical results.

Recently, three new research tasks have been undertaken. One involves the extension of some earlier analytical work to predict the large deformation elastic-plastic dynamic response of general thin shells to transient loading. The second involves devising concepts for the containment and control of fragments from burst turbine or compressor rotors, and methods for predicting the response of such devices. The third involves the development of equipment with which to study and to conduct parametric measurements on a divergence-induced stall-flutter device in which wall interference effects are believed to be prominent.

The wind tunnel facilities in the Aeroelastic and Structures Research Laboratory were busy with a variety of projects during the year. The five-by-seven-foot flutter tunnel was active with graduate and undergraduate projects, including effects of a cambered keel on the sideslip of a sailboat, effects of suction on the aerodynamic characteristics of a wing, drag on many configurations of the human hand as applied to swimming, dynamic effects of a refueling drogue, and visual flow of the underside of an aircraft with and without stores. Professor Miller's group continued research on the flow visualization of vortex shedding effects on helicopter blades.

The one-by-one-foot low turbulence tunnel was used several times by the Department of Meteorology to calibrate hot wire and cup anemometers.

Professor Larrabee did research on automobile and bus bodies. Several student projects included drag on rocket nose cone shapes, the torque and rpm of a rubberband propeller motor under flight conditions, the wake decay behind a grid, and the drag of a tumbling cylinder.

The one-by-one-foot tunnel in Building 17-A was used for several freshman seminar demonstrations concerning drag on a sphere, aerodynamics of a baseball, and flow measurements in the wake of an airfoil.

**EXPERIMENTAL ASTRONOMY LABORATORY**

During the past year, the Experimental Astronomy Laboratory, under the direction of Professor Winston R. Markey, continued research in navigation systems and, through additional support, was able to provide thesis topics in the following areas:

1. Marine navigation
2. VTOL aircraft terminal guidance
3. SST (Supersonic Transport) navigation
4. Airborne gravimetry
5. Gravity research
6. Satellite geodesy
7. Satellite oceanography
8. Interplanetary guidance

SPACE PROPULSION LABORATORY
In addition to Professor Kerrebrock, who directs the activities of the Space Propulsion Laboratory, faculty members who take part in the laboratory activities are Professors Hoffman, Lewellen, McCune, and Solbes.

Research in the Laboratory continues to be focused mainly on nuclear Magneto Hydrodynamic (MHD) space power systems and nuclear rockets. Professors Kerrebrock, Hoffman and Solbes, with the aid of Reiner Decher and Michael S. Hsu, conducted experiments on the large non-equilibrium MHD generator, which have yielded a good understanding of the internal current flow patterns in the device. Professor Solbes and Takashi Nakamura continued to study the electrothermal instability, both theoretically and experimentally. Dr. James P. Reilly carried out detailed measurements of the heat transfer and skin friction in a non-equilibrium MHD generator channel.

Professor Lewellen is studying the fluid mechanics of swirling flows, such as those in gaseous nuclear rockets and fluidic control devices. He also supervised an experimental study of heat transfer from a turbulent boundary layer subjected to a strong negative gradient in wall temperature. This is relevant to nuclear rocket nozzles.

Professor Kerrebrock and Michael Monsler are studying the stability of gases with very large radiant energy fluxes, such as are proposed for the gaseous nuclear rocket. Dr. David B. Stickler, with the supervision of Professor Gordon C. Oates and Professor Kerrebrock, completed an experimental and theoretical study of liquid oxidizer-solid fuel combustion.

This year the Laboratory had two foreign visitors. Professor Vadim Alfjorov of the University of Moscow participated in the MHD power research from January through June, 1968; Dr. Jerzy Milewski of the Polish Academy of Fluid-Flow Machines was a member of the group from April through June, 1968. Student and faculty interest in the research program continues at a high level.

MAN-VEHICLE CONTROL LABORATORY
The Man-Vehicle Control Laboratory, under the direction of Professor Young, involves the collaboration of Professors Li and Meiry.
The Laboratory is supported entirely by three grants from NASA headquarters. Two of them are continuing programs, in the fields of manual control (orientation in space), and modeling of vestibular characteristics. The third is a new grant in the area of life support systems, involving definition of promising new areas and some seed research in biotechnology. On this last project the Laboratory is assisted by Professor Robert C. Reid of the Department of Chemical Engineering.

With the exception of Professor Li, the entire Laboratory staff is located on the first floor of the Center for Space Research.

All of the projects in the Laboratory involve the application of control theory to problems concerning men, their physiological subsystems, or their interaction with a vehicle. The following areas have been emphasized during the year:

1. Manual control modeling
   Effects of roll motion cues
   Effects of roll and yaw motion cues
   Use of variable feel control stick
   "Inverse optimal" manual control problems
   Bayesian learning model for skill acquisition
   Digital adaptive control

2. Display research
   3D display development
   VTOL integrated display
   "Anti-vertigo" display
   Development of a "head position sensor"

3. Vestibular research
   Unified model for vestibular function
   Non-linearities in rotation sensing
   Direction preponderance (bias) in semicircular canals
   Physical modeling of semicircular canals
   Adaptation and habituation

4. Eye movement modeling
   Vestibular effects
   New hybrid model for eye tracking
   Eye movement in learning to read

5. Postural and neuromuscular control
   Research on balance reflex
   Basic neuromuscular modeling
   Data presentation of muscular activity in skilled action
   Postural control for EVA (Extra Vehicular Activity) propulsion system
6. Life support systems
   Instrumentation for cerebral blood flow
   EVA propulsion
   EVA and cabin atmospheres
   Control of closed ecological systems

   The Laboratory staff plans no major changes in direction next year, although it is planned to stimulate a growing interaction with life scientists, principally at Harvard Medical School.

GAS TURBINE LABORATORY

The Gas Turbine Laboratory, under the direction of Professor Taylor, continues to be supported by grants-in-aid from the General Electric Company and the Allison Division of General Motors Corporation. A contract with the Power Branch of the ONR terminated in January. There is also a continuing contract with the National Science Foundation.

The close of the 1967-68 school year brought a number of important personnel changes in the Laboratory. Professor Taylor, Director of the Laboratory since its inception in 1947, came to retirement age this year and ended his full-time work in June. Professor Kerrebrock was appointed the Laboratory’s second director to take over from Professor Taylor on July 1, 1968. Professor Philip G. Hill of the Department of Mechanical Engineering left the Laboratory to take a position as Head of the Mechanical Engineering Department at Queen’s University in Kingston, Ontario.

Among the significant research results that can be mentioned are careful experiments with a transonic compressor wheel which indicate that the drag increase near a relative Mach number of unity is several times larger than the wave drag predicted by theory.

In addition, knowledge of the effect of a favorable pressure gradient on the behavior of a turbulent boundary layer has been extended into the compressible domain and to higher Reynolds numbers. The region where a turbulent boundary layer reverts to laminar has been more fully defined.

Among those researches in progress, it can be mentioned that hot-wire measurements of turbulence intensity and Reynolds stresses in a boundary layer with the pressure gradient adjusted to give zero wall friction are nearing completion.

Careful flow and power measurements are being obtained to compare a compressor with conventional blades with one which has unconventional blade shapes which have given promising preliminary results.

In addition, flow-visualization studies of radial-flow turbine and com-
pressor blading are progressing. The developing flow in a rectangular channel rotating about a transverse axis is also being studied in an attempt to improve understanding of centrifugal pumps and compressors.

The significant effect of a small mount of swirl on the turbulent mixing of an axisymmetric jet is being measured and a predictive theory is being extended.

The size of condensing droplets in an expanding flow are being measured by light-scattering techniques.

An investigation of the flow regimes in axial-to-radial diffusers has been started.

A theoretical and experimental investigation of the flow of a turbulent boundary layer over fences of varying heights has been started. Another investigation in the initial stages concerns the effects of time-varying energy addition on the separating and diffusing characteristics of turbulent boundary layers.

A method for testing large turbo-machines on site was designed and tested and found to be very promising.

**FLIGHT TRANSPORTATION LABORATORY**

The Flight Transportation Laboratory, under the direction of Professor Miller and with the collaboration of Professor Simpson, is concerned primarily with research in air transportation systems. The Laboratory is systems-oriented and is concerned more with total system management and operation than with details of aircraft design.

During the past year, there was a continued investigation of the vehicles and networks required for a viable short-haul air transportation system in densely built-up areas. Five reports were published on these general problems and it is expected that four new ones will be available by the end of the coming year. Interest on the part of graduate students continues high, with the only limitation being the funding level available and the supervisory limitations of the small academic staff. If the funding level could be raised, the possibility exists of hiring a full-time staff member who could assist the two participating faculty members in supervisory activities. Because of the great interest in transportation in general it is expected that once the funding situation stabilizes, it may be possible to raise the level of Laboratory activities in order to accommodate all those who wish to do graduate theses in flight transportation.

**INSTRUMENTATION LABORATORY**

Educational activities have continued to play a major role for the Instrumentation Laboratory during the 1967-68 academic year. Some 13
faculty members of the Department have made significant contributions to the Laboratory while five members of the Laboratory staff have served as lecturers for the Department. As Educational Director, Professor Wrigley worked with a group including Professors Hollister, Li, Markey, Meiry, Mueller, Potter, Vander Velde, Whitaker and Young, and Drs. Alonso, Robert H. Battin, Elmer J. Frey, John Hovorka and Stern. As of April, 1968, some 375 students, ranging from freshmen to candidates completing thesis work for the doctorate, were associated with the Laboratory. At the same time, 90 Laboratory staff members were enrolled as special students at M.I.T. and 81 took work in other schools. During 1967-68, 26 students completed theses associated with work in the Laboratory. In April, 1968, the Laboratory was providing part-time employment for 144 students.

Sponsored research in the Instrumentation Laboratory increased by about eight per cent during the 1967-68 academic period to a present level of over $53 million a year. The list of sponsors remained unchanged, most of the support coming from the United States Air Force, the United States Navy and NASA, the Air Force share being somewhat less than one-quarter of the sum provided by the other two. Projects of lesser magnitude are in progress for the United States Army, for the Federal Aviation Agency (FAA), for the Atomic Energy Commission and for the Boeing Aircraft Company. Thirty-seven projects are being carried out for these sponsors under the direct operating supervision of Institute Professor Emeritus Draper as Director and Forrest E. Houston, Ralph R. Ragan and Roger B. Woodbury as Deputy Directors. Joshua B. Feldman continued to act as Executive Officer. Robert Weiser of the M.I.T. Lincoln Laboratory served as Deputy Director for software development.

Significant developments occurred in substantially all the major programs of the Laboratory during the 1967-68 academic year. Flight testing of the Apollo guidance and navigation system has gone forward with two more unmanned flights. One launch with only a lunar excursion module aboard was not completely successful, but did provide results showing that the Laboratory guidance and navigation system worked without fault so far as the existing configuration would allow. The second Saturn V launch with the Instrumentation Laboratory system in a command module had difficulty due to rocket engine malfunctions but demonstrated that the guidance and navigation system operated with performance well above specification requirements. The system that will fly next fall in the first manned test of the Saturn V system is now ready and operating at satisfactory performance levels.
All the APOLLO guidance and navigation system hardware is not only designed but has been manufactured and now awaits flight operations. The Instrumentation Laboratory work on APOLLO hardware remains at the relatively low level needed for testing and produce improvement, but the development, realization and testing of software appears to require the present level of activity for at least two and possibly more years into the future.

Work for the United States Navy on guidance for the POSEIDON Fleet Ballistic Missile System has progressed through design and preliminary production stages with flight tests expected early in 1969.

Stabilization and control for the Orbiting Astronomical Observatory (OAO) Telescope project of NASA has been completed in design and is now being produced in the limited quantity needed for OAO operations. Laboratory testing is in progress and the first flight is expected early in 1968.

Control, navigation and guidance for the Navy's Deep Submergence Project has been designed, built, and is now in the process of being delivered to the first test vehicle. The problems associated with this process still require much attention, but software development and production activities must absorb much effort during the months ahead.

The SABRE ballistic guidance system for the United States Air Force has been built from Instrumentation Laboratory designs by the Laboratory itself, by the A-C Electronics Division of General Motors and by the Autonetics Division of the North American Rockwell Corporation. Laboratory and centrifuge tests of these prototype systems have demonstrated that they meet the accepted performance goals. Test work and advanced design is continuing pending government decisions on future applications of the SABRE system.

Radiation field pattern plotting studies have been interrupted by a delay in funding from the FAA. The equipment needed for accurate plotting of these fields has been designed and built. Work was interrupted for some months because of lack of funding, but is now being started again.

VTOL and helicopter control, navigation and guidance work for the U.S. Army and for the Electronics Research Center of NASA has been proceeding slowly because of low funding levels. The basic importance of this work is generally recognized, especially as it is closely associated with educational interests in the Department. Every effort is being exerted to keep the VTOL-helicopter work alive until its significance is recognized and proper support is available.

An important development in progress for several years has been
formalized by the recent establishment of the Division of Scientific Technology under Philip N. Bowditch. This group directs its efforts toward the engineering, design, construction, testing and operation of apparatus and systems needed for research in pure and applied science. Emphasis is on assistance for projects conceived and directed by M.I.T. faculty members not necessarily in the Instrumentation Laboratory who are either working alone or in cooperation with scientific organizations outside the Institute. The new Division is now working with the Center for Earth Sciences and the Woods Hole Oceanographic Institute in the design, construction and installation of a sensor network for collecting information on flow, temperature, salinity and other conditions within selected bodies of ocean water. Various other projects are either in progress or being formulated.

The new division is enthusiastically accepting its responsibility for determining, defining and exploiting complementary areas of cooperation for the Laboratory and the scientific community. A number of possibilities are now being discussed that are expected to result in significant and interesting work as future projects.

Not yet near completion, but well into theoretical analysis and design are twin projects for the Electronics Research Center of NASA that are directed toward the realization of inertial sensor gyro units and specific force integrating receivers with greatly improved performance, reliability and operating life. For both of the two new inertial sensors it is expected that development will be complete, with engineering information available to start prototype design and the documentation of specifications and manufacturing information in about one year. Production should follow about one year later.

When the new sensors are in production, inertial control, navigation and guidance systems with performance characteristics to revolutionize guidance of submarines, aircraft, missiles and spaceships will become operational realities. This means that during the next few years the Instrumentation Laboratory will be credited with another great contribution to the technology of modern flight transportation.

In the present time of sharply curtailed support for research, engineering, and technology, the Instrumentation Laboratory continues to hold its position of preeminence among organizations dealing with the frontiers of technology in the field of control, navigation and guidance. The years just ahead will bring some difficulties but it is unlikely that the Laboratory's operations will be affected seriously.
The past year was used for maintenance and rebuilding much of the equipment in the Wright Brothers Wind Tunnel. This work was done part-time by Professor Bicknell and Allan R. Shaw, as a first step in getting the tunnel back to an active level of aerodynamic research.

Although no effort was made to attract such work, the tunnel was busy for about one-third of the last fiscal year with project testing. The largest project was the testing of a wing and a complete model for Professor Koppen. This model is of a feeder line airplane with short field capability.

Other work was for the M.I.T. Lincoln Laboratory, on a model of their CAMROC (Cambridge Radio Observatory Committee) antenna radome. This work involved construction and calibration of a grid which produced a shear flow simulating the earth's boundary layer. Toward the end of the fiscal year, tests were run on a model of the deep submergence rescue vehicle for the Department of Naval Architecture and Marine Engineering.

There has been a rekindling of interest in subsonic airplanes and an awareness of the problems of environmental aerodynamics. There is increasing interest in V/STOL aircraft. The Wright Brothers Wind Tunnel has capability or potential capability in all of these areas.

In the immediate future, it is planned to hire two people, a research assistant and a technician, to be associated with the tunnel full time. The experience of the last few years shows that a laboratory of this sophistication cannot be operated continuously other than by its own staff. A moderate effort should produce a full schedule of research work for the next year.

The wind tunnel can be a strong factor in the education of engineering students. Contact with the industry through work on their design problems can be an additional source of support for students interested in design but unable to obtain support at present.

In the longer view, the tunnel needs to be drastically revised, with a drive system for velocities below 30 miles per hour and, most important, a new rectangular test section. Provision for floor suction is necessary for automotive testing. The testing of buildings may require a variable geometry test section. Research and planning in these directions will be carried out in the coming year.

LABORATORY FOR PLASMA PHYSICS AND SPACE SCIENCES
The Laboratory for Plasma Physics and Space Sciences came into being as a research group in June, 1967. The group consisted originally of
Professors McCune and Heinrich J. Volk. In February, 1968, Professor Tam joined the group. Several graduate students engaged in their doctoral research round out the personnel of the laboratory.

During 1967-68, the Laboratory has been engaged in the study of various types of instabilities occurring in plasmas, as well as their eventual effect on the evolution of plasma systems, interacting with electric and magnetic fields.

Some of the major results for this period are reported in four recently completed doctoral theses. The doctoral thesis of Dr. James Callen is being considered for publication by the M.I.T. Press as a research monograph.

In addition, work has begun on the fundamental propagation properties of absolute and convective instabilities, with particular emphasis on multidimensional systems and the effects of inhomogeneities. This work is supported by NASA under the basic grant to the Center for Space Research.

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DEPARTMENT OF CHEMICAL ENGINEERING

Special attention was focused on two main areas during the year: (1) the undergraduate and graduate curriculum revisions were actively pursued and several new subjects were introduced; (2) the Department studied the ways in which the program could be made more effective for those students planning industrial careers.

UNDERGRADUATE INSTRUCTION

A considerable portion of the revised undergraduate curriculum discussed in the last report was introduced during the year. A new required sophomore subject, Staged Cascades in Chemical Processing, was given for the first time by Professors P. L. Thibaut Brian, William H. Dalzell and David A. Diener. It involves cascade theory of staged operation as used in solvent extraction, distillation, absorption, gaseous diffusion and chemical reaction and develops the concepts of reflux and ideal cascades. It introduces the students to graphical analysis, finite difference methods, numerical iteration techniques and computer programming.

A new undergraduate subject in polymer material science was given by Professor Allan S. Hoffman and Professor Ioannis V. Yannas of the
Department of Chemical Engineering. It covers the principle of macro-
molecular structure, its relation to properties of polymers and the appli-
cation to the design of engineering materials.

The revision of the three-subject sequence on unit operations and
transport processes by Professor Kenneth A. Smith is continuing and
two new subjects in this area will be introduced during the coming aca-
demic year. The present undergraduate subject in chemical kinetics is
being modified to include applied kinetics and reactor design and will
cover fundamental kinetics, ideal reactor analysis and reactor design.
The development of the sophomore, junior, and senior project labora-
tory work has continued and is giving the student the opportunity to do
closely supervised group research, analysis and design at an early stage
in his program. These subjects together with Thermodynamics, Industrial
Chemistry, Structure and Properties of Non-Metallic Substances, Process
Design, and thesis complete the portion of the undergraduate program
given by the Department.

GRADUATE INSTRUCTION

The graduate subjects given by the Department are being organized to
permit integrated elective programs in areas such as engineering opera-
tions, combustion and radiative transfer, thermodynamics, industrial
chemistry processing, chemical reaction technology, chemistry and phys-
ics of polymers and surfaces, applied mathematics, and dynamics and
control of chemical processes. Regardless of the area of concentration,
the Department believes it is desirable for all new graduate students to
take a core program of subjects in thermodynamics, fundamentals of
heat and mass transfer, mechanics of fluids, and industrial chemistry or
the School of Chemical Engineering Practice. These fields would be
combined with the main subjects in the various areas given each year.
More advanced and specialized subjects which will be taken primarily by
those going beyond the Master's degree will be given biennially. In order
to implement this program, several new subjects are being developed
and will be introduced in the coming academic year.

The School of Chemical Engineering Practice continued its operations
at the Bound Brook plant of the American Cyanamid Company and at
the AEC (Atomic Energy Commission) Oak Ridge National Laboratory.
During the past year 34 students attended the two stations. In April,
representatives from the American Cyanamid Company and the Depart-
ment commemorated the tenth anniversary of the operation of the
Bound Brook station with a seminar, "Education/Industry Interface in
the Chemical Industry."
INDUSTRIAL ORIENTATION

For a number of years there has been growing concern in both industry and the universities about the apparently diverging paths of engineering education and industrial engineering practice. This has been due to the increasing attention given to science, engineering science, and research in engineering curricula.

The majority of our students enters chemically based industry and the Department attempts in a number of ways to give the students orientation and training for such careers. In addition to the emphasis on science and research, our program has a major amount of time devoted to industrial aspects. The School of Chemical Engineering Practice offers a unique experience in industrial process projects under the direct supervision of the M.I.T. Faculty, and about two-thirds of the graduate students elect this program. These students handle development and engineering problems under plant conditions, then must sell their conclusions and recommendations to the company personnel; the value of their contributions is demonstrated by the actual operation. The faculty is also active in industrial consulting and all of the Assistant Professors are encouraged to spend their summers in industrial work. With this background the staff interjects an industrial flavor into many of the subjects, particularly those in process design and project laboratory. In addition, the Department has as Visiting Professors men from industry who, for an academic year, give subjects and seminars, and spend time with the students on their research. The desirable degree and character of the interaction of a chemical engineering department and industry was the main topic of discussion at our Visiting Committee meeting this year and as noted in the section on graduate curriculum, it was the focus of a joint seminar at the Bound Brook practice school this spring. This will continue to be a subject of discussion with a group from industry during the coming year.

STUDENTS

For the period July 1, 1967, to June 30, 1968, the Department awarded 21 Bachelor's degrees, 62 Master's degrees, four Chemical Engineer degrees and 11 doctoral degrees.

STAFF ACTIVITIES

The Department has had the benefit of the contributions of four distinguished visiting scholars during the year. Dr. Mark Phillips Freeman of the American Cyanamid Company spent the year as Visiting Professor
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of Chemical Engineering. Three Visiting Engineers worked with members of our faculty: Professor Nikolai Michael Korolkov of the Riga Polytechnical Institute, U.S.S.R., and Mr. Esteban Brignole of the Universidad Nacional del Sur, Argentina, worked with Professors Thomas K. Sherwood and J. Edward Vivian; and Dipl. Ing. Heiko Barnert of the University of Aachen, Germany, worked with Professor Brian.

Assistant Professor Lawrence B. Evans was promoted to Associate Professor and Dr. David A. Diener and Dr. James J. Noble were appointed Assistant Professors.

Professor Raymond F. Baddour was on sabbatical leave during the year and was awarded an NSF (National Science Foundation) Faculty Fellowship for medical engineering work at the Massachusetts General Hospital. He served as chairman of the Gordon Research Conference on Separation and Purification and as a member of the Editorial Board of Separation Science.

Professor Brian served as a member of the Committee on Program and also as a member of the Committee on Research of the American Institute of Chemical Engineers, and as the School of Engineering representative on the M.I.T. Committee on Educational Policy.

Professor Edwin R. Gilliland served as a member of the Board of Visitors for the Department of Chemistry of Tufts University, as a member of the Industrial and Professional Advisory Council of Pennsylvania State University, and as a consulting professor to the College of Engineering of Louisiana State University. He was chairman of the Engineering Section and chairman also of Division III of the National Academy of Sciences and a member of the Finance Committee of the Academy. He was on the Advisory Board of the A.I.Ch.E. Journal. He served as a member of the Management Advisory Council of the Oak Ridge National Laboratory of the AEC and as a consultant to the President's Science Advisory Committee.

Professor Hoyt C. Hottel was chairman of the American Committee on Flame Research, a member of the National Academy of Sciences — National Research Council (NRC) Committee on Fire Research, and a member of the NRC Advisory Panel to the National Bureau of Standards.

Professor Herman P. Meissner served as a member of the Office of Saline Water (osw) Evaluation Committee for Ion Adsorption Processes.

Professor Edward W. Merrill was a member of the contract Review Committee and consultant to the Director of the National Institute of Arthritis and Metabolic Diseases. He served as consultant to the Massachusetts General Hospital, the Beth Israel Hospital and the Peter Bent Brigham Hospital. He was a member of the Editorial Board of the
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Journal of Biomedical Materials and a member of the Scientific Advisory Council of the American Heart Association.

Professor Harold S. Mickley continued as Director of the M.I.T. Center for Advanced Engineering Study. He also was chairman of an M.I.T. Faculty Committee reviewing the future of the Graduate School.

Professor Robert C. Reid was chairman of the Lecturer Nominating Committee and chairman of the Technical Program Committee for the 1968 Montreal Meeting of the American Institute of Chemical Engineers.

Professor Charles N. Satterfield spent his sabbatical leave revising his text on catalysis. He was a member of the Editorial Board of Industrial and Engineering Chemistry and of the Editorial Board of I. & E.C. Design and Development Quarterly.

Professor Thomas K. Sherwood was chairman of the National Academy of Sciences — National Academy of Engineering Committee on Air Quality Management, a member of the Freezing Review Committee of the Office of Saline Water, and a member of the I. & E.C. (Industrial and Engineering Chemistry) Advisory Committee of the American Chemical Society. He was chairman of the osw Research Symposium.

Professor Glenn C. Williams served as Vice President and Director of the Combustion Institute, as a member of the NDEA Fellowship Review Board, as a member of Facilities Grants Review Board of the U.S. Office of Education, and as a member of the Panel on Electrically Powered Vehicles of the Department of Commerce.

Professor Evans was vice chairman of the Film Loops Subcommittee and a member of the Educational Projects Committee of the American Institute of Chemical Engineers.

Professor Hoffman was a member of the Editorial Advisory Board of Polymer Engineering and Science and a member of the Plastics Education Committee of the Society of Plastics Engineers.

Professor Adel F. Sarofim was secretary of the American Flame Research Committee.

Professor Wolf R. Vieth was an Exchange Visitor with the Technical University of Berlin and he also served as local arrangement chairman for the National Symposium of the Industrial and Engineering Chemistry Division of the American Chemical Society.

Professor Michael Modell was chairman-elect and membership chairman of the Catalysis Club of New England.

Professor Wolf R. Vieth resigned to become Professor and Head of the Department of Chemical Engineering at Rutgers University, effective July 1, 1968. Assistant Professor Allan S. Douglas has accepted a position at Gulf General Atomics, and Assistant Professor Diener has ac-
cepted an appointment as Associate Professor of Mathematics at Hartwick College. The Department appreciates the contributions these colleagues have made as members of our faculty and we are particularly indebted to Professor Vieth for his long service to the Department and for his able direction of the School of Chemical Engineering Practice. To them we extend our best wishes for success in their new careers.

STAFF HONORS
Professor Hottel received the Founders Award of the American Institute of Chemical Engineers, and Emeritus Professor Thomas B. Drew was the 1967 recipient of the Max Jakob Memorial Award, sponsored by the American Society of Mechanical Engineers and the American Institute of Chemical Engineers. Professor Reid was selected as the 1967 Institute Lecturer of the American Institute of Chemical Engineers.

STAFF RETIREMENTS
After many years of distinguished service on the M.I.T. faculty, Professor Hoyt C. Hottel retires at the end of the current academic year. Professor Hottel is internationally recognized for his outstanding contributions in radiative heat transfer and combustion. He has received many honors and awards and has contributed importantly to the development of the many doctoral students who have worked under his guidance. The Department is fortunate that he will continue on a part-time basis as Emeritus Professor and Lecturer.

Harold H. Carter retired as Technical Instructor after more than 50 years of service at the Institute. He will be long remembered by the thousands of undergraduates and graduate students in chemical engineering who sought his assistance in their laboratory and thesis work. We are pleased that Mr. Carter will continue on a part-time basis.

RESEARCH
COMBUSTION AND RADIATIVE HEAT TRANSFER
The Fuels Research Laboratory, under the direction of Professors Hottel and Glenn C. Williams and in collaboration with Professors Adel F. Sarofim, Dalzell, Jack B. Howard and James J. Noble, has continued its program on kinetics, heat transfer and flow in combustion processes.

Carbon black formation from residual fuel oils was studied in a vertical flow furnace to determine which process variables are important and to determine the effect of these variables on the properties of the carbon black formed. Clouds of oil droplets of almost monodisperse particles in the range 28 to 100 microns were charged continuously into an iso-
thermal furnace at 2,000° to 2,900°F. The oil droplets, consisting of two commercial carbon black residual fuel oils and naphthalene, were vaporized and pyrolyzed in a hot gas stream consisting of the combustion products of a natural gas-air flame. The pyrolysis reaction was quenched with steam after residence times of 40 to 100 milliseconds, the carbon black collected on a sintered metal filter and the gas stream analyzed on a gas chromatograph. The carbon black produced in the experimental reactor had properties similar to that produced in actual production furnaces. The formation of carbon black fits a model consisting of a nucleation step followed by simultaneous gas phase and surface reactions. Nucleation is the most important step and determines the final size, surface area, per cent extractable and cluster chain length of the carbon black product. The nucleation step has an activation energy in excess of 100 kcal/mole, and occurs in a period of time short compared to the few milliseconds required to vaporize the oil droplets. The gas phase reaction generates species which add to the carbon nuclei. The activation energy for this process was in the range 35 to 45 kcal/mole for the fuels used. The surface-growth step had an activation energy of 3 to 7 kcal/mole, with the pure feed (naphthalene) having the highest activation energy.

The study of turbulent boundary-layer combustion has continued, with emphasis on combustion in hybrid rocket motors under conditions where burning rate is controlled by fuel pyrolysis and chemical kinetics. The importance of oxygen concentration is evaluated by measuring the oxygen concentration at the fuel surface at different burning rates and the increase in pyrolysis rate resulting from a given surface oxygen concentration. The experimental technique includes the burning of flat plates of polymethylmethacrylate in oxygen, with concentration and temperature measurements by probe sampling and sodium D-line reversal, respectively.

A program to study the pollution problems associated with public utility power station furnaces and with solid refuse disposal has been initiated. A preliminary study has shown that NO formation in stationary power plants can be reduced significantly by flow-and-mixing modifications in chamber and burner design, but that lack of sophistication in making such changes can result in a replacement of NO by other pollutants associated with incomplete combustion of CO or coked particles or with soot formation. Though existing literature permits a rough evaluation of effects of burner design, mixing, and combustion progress on pollutant formation, shortcomings in the available models both of flow and of chemical kinetics limit the validity of the conclusions.
The removal of sulfur dioxide from stack gases by injection of limestone and dolomite particles was studied. This reaction is interesting both because of its importance in air pollution control and because of its similarity to the pulverized-coal burning problem. A generalized reaction mechanism was formulated which includes encrustation by condensed reaction products as one of the rate-controlling processes. The model was tested using data supplied by the National Center for Air Pollution Control. The analytical techniques developed offer considerable potential for elucidating details of the reaction mechanism and for designing practical systems.

Work was begun on the problem of solid refuse disposal with emphasis on power generation using refuse as fuel. Such a process appears advantageous with respect to air pollution, since credit from the power generated would tend to offset the cost of sophisticated equipment needed for preventing air pollution. Work to date includes mathematical modeling of drying, pyrolysis, gas-phase combustion, heterogeneous combustion, and a computer aided systems analysis of incineration.

The Department has continued its active research program on radiative transfer under the direction of Professors Hottel and Sarofim, with the collaboration of Professors Dalzell and Evans. The major emphasis has been on the development of methods for predicting radiative transfer in scattering media, radiative properties of surfaces, interaction of radiation and other modes of heat transfer, and heat transfer from luminous flames.

The development of numerical methods for the solution of problems of viscous flow in enclosures involving the natural circulation of radiation-absorbing-emitting fluids has been continued. Such methods are of practical importance in the digital computer simulation of industrial glass furnace operations and, indirectly, the modeling of atmospheric circulations. Since flow and heat transfer interact in such problems, their analysis necessitates the simultaneous solution of the energy equation and the equations of fluid motion as a coupled set. The numerical difficulties encountered include those associated with instability and slow convergence of the methods used to solve the Navier-Stokes viscous flow equations and those associated with the non-linear and action-at-a-distance characteristics of the radiation terms in the energy equations. The sources of the problems encountered in the solution of the flow equations have been identified with the formulation of the boundary condition on vorticity and with failure to satisfy conservation of the convective terms. Significant improvements in finite-difference methods for the flow equations have resulted from the investigation. Relative to pre-
vious work, these include a reduction in computation time of about fivefold, and unconditional stability with respect to the maximum allowable Rayleigh number. Numerical stability of the finite-difference solution of the flow equations has been partially explained via rigorous treatment of the one-dimensional problem. The method has been employed successfully to predict flow patterns in a gray fluid confined in a two-dimensional enclosure heated from above and cooled at the sides. The flow pattern is, as expected, bicellular, rising at the center. A bottom-insulated enclosure acts as though heated partially from below if the enclosure contents are of high transmittance (optically thin system); as though having an effective high thermal conductivity, with radiative “conduction” added in, if the system is optically thick. In consequence, the fluid circulation rate passes through a maximum with respect to optical thickness.

The numerical investigation described in the previous paragraph is currently being continued with the goal of developing a reasonable model of industrial glass furnace operation. Physical and mathematical models each have their elements of superiority. Physical models can allow for geometrical complexity, and provide visualization of phenomena; mathematical models are able to include dimensionless parameters not possible to satisfy between a physical model and its prototype. The use of both, each in its regime of superiority and both in the regime of their overlap, should greatly strengthen our understanding of the glass tank. A start in this direction has been made by a physical study of residence-time distribution in a small model using glycerine.

The solution of heat transfer problems in which both radiation and conduction are important is usually accomplished by evaluating the two contributions to heat transfer independently. This is because the coupled problem, described by non-linear integro-differential equations, cannot in general be solved analytically. Finite-difference methods have been developed for the solution of transient radiation-conduction problems in one and two dimensions. The methods are based on transient integration and appear to be unconditionally stable with respect to time increment. They have been applied successfully to the solution of simultaneous radiation and conduction in one-dimensional gray media of intermediate optical thickness and two-dimensional optically thick media. Extension of the method to two-dimensional media of intermediate optical thickness is currently being investigated.

The study of the optical constants of soot has been motivated by interest in radiation from luminous flames and in the interpretation of light-scatter measurements to determine soot size and concentration. Optically smooth surfaces have been formed by high-pressure compacting of soot.
pellets, and reflectivity for polarized radiation measured over the visible (0.4 to 0.8\(\mu\)) and infrared (2.5 to 10\(\mu\)) regions of the spectrum. The soots studied had carbon-hydrogen atom ratios of 4.5 and 16. The optical constants calculated from the above reflectivity measurements were fitted to a dispersion model which was then used to predict optical constants in the wavelength range 0.8-2.5\(\mu\). It was found that variations in the free-electron contribution of the dispersion model, in amounts consistent with variations observed in the hydrogen-to-carbon ratio of different soots, provided an explanation for the wide variation in the values of the optical constants reported in the literature. The observed variations were shown to have a significant effect on the concentration of soot calculated from scatter measurements, but a small effect on heat-flux calculations compared to the effect of uncertainties in soot concentration.

The enormous difficulty of determining radiative interchange between a non-isothermal gas and its confining walls under conditions of radiation-convection interaction can be reduced greatly by invoking the mixed-gray-gas concept, developed in the Department; but the validity of the approximation has been questioned. An elaborate machine program has compared the mixed-gray-gas method with the much longer rigorous method and found, in application to problems involving water vapor, an agreement between the two methods that is excellent.

The factors that determine the optical properties of pigment coatings are being investigated experimentally and theoretically. Calculational methods have been developed for the prediction of the amount and angular distribution of the radiation reflected by pigment particles suspended in a transparent matrix for the case in which the particles are far enough apart to be treated as independent scatterers. Experiments are being carried out to test the calculational results and to study the properties of particle suspensions in the range in which the particles can no longer be treated as independent scatterers.

**CATALYSIS, APPLIED KINETICS, AND REACTOR TECHNOLOGY**

Trickle-bed reactors have come into widespread use in the petroleum industry over the past ten years for hydrodesulfurization and hydrocracking of heavy oil fractions and high boiling stocks, as well as for hydro-treating of lubricating oils. The application of trickle-bed processing in the chemical industry, however, is at present minimal, probably due largely to the lack of design information. These three-phase reactors may readily suffer upon scale-up to large diameter units, through loss of contacting efficiency and problems from heat effects. The flow distribution over the catalyst varies widely with flow rates, system properties, and
reactor design and the liquid residence time distribution is much more sensitive to system properties than for the case of single-phase flow. A doctoral thesis by Peter F. Way, under the supervision of Professors Sherwood and Charles N. Satterfield, has as a primary purpose the preparation of a critically evaluated design procedure for trickle-bed reactor systems, based on all information available in the literature. A second purpose of the study is to investigate the effect of certain critical system parameters on reaction rates in trickle-beds. Suitable experimental studies are being planned, using the isomerization of cyclopropane on silica-alumina catalyst as a model reaction.

In a catalytic reaction such as the oxidation of an organic vapor, reaction may be initiated on the surface of a catalyst and then be propagated into the homogeneous zone around the catalyst. The performance of a catalytic reactor may be affected profoundly by such "hetero-homogeneous catalysis," but very little has been published about the phenomenon and much of the evidence is indirect. A study by Douglas H. Cortez under the supervision of Professor Satterfield is aimed at obtaining better understanding of the conditions under which this phenomenon may occur. Experimental studies are presently being conducted of the catalytic oxidation of 1-hexene over platinum screen catalysts at gas temperatures of 280° to 450°C and atmospheric pressure. Careful sampling with a water-quenched probe revealed no concentration changes over the distance of 0.1 to 2.0 inches downstream from the screen catalyst, indicating that under these conditions no significant homogeneous reaction was occurring in this gas space. However, homogeneous reaction may be occurring very close to the catalyst surface, in a zone substantially thinner than the effective film thickness. Further examination of previous experimental studies suggests that the hetero-homogeneous mechanism may become more important at lower pressure and higher catalyst temperatures than those we have been able to investigate thus far. The present work is also revealing substantial new information concerning the mass-transfer and heat-transfer characteristics of woven wire geometries, extinction and ignition phenomenon in exothermic catalytic reactions and the factors influencing the activation and deactivation of platinum metal catalysts.

The recent advent of molecular sieve catalysts is having a major impact on the processing of hydrocarbons, particularly in petroleum refining. The reasons for their unusual reaction characteristics are far from clear but it is evident that the diffusional characteristics of product and reactant molecules in the extremely tiny pores in the catalysts can profoundly affect the course of the reaction. A study by James R. Katzer under the supervision of Professor Satterfield has focused attention on the alkyla-
tion of benzene with propylene to form cumene as a model reaction system to characterize some of the phenomena that occur in zeolite catalysis. Work thus far has focused on the diffusion characteristics of benzene and cumene in the liquid phase in two zeolites of commercial importance: hydrogen mordenite and Type Y zeolite, both studied as powders comprising individual crystals. Diffusion rates of benzene and cumene in hydrogen mordenite have been found to be very slow, and counterdiffusion of the two species does not occur within the mordenite pores. Since hydrogen mordenite is known to be an active catalyst for the alkylation of benzene to cumene, this leads to the important conclusion that, at least for molecules of this size, reaction must all occur on catalyst sites outside the pores. Studies of the diffusion of cumene in hydrogen mordenite show that the diffusion coefficient decreases substantially with an increase in the length of time that the cumene had been in contact with the zeolite before the diffusion run was carried out. Studies by electron spin resonance show that radical ions are formed when cumene is in contact with hydrogen mordenite and periods of many hours or days at room temperature are required for the maximum intensity signal to be reached. This strongly suggests that a gradual blocking of the pores may occur by chemisorption. Studies with Type Y sodium zeolite and the same material after being ion exchanged to form a catalytically active material show a dramatic increase in the diffusion rate with the nature of the cation present. This has considerable implications in catalysis since it implies that reports of the effect of the nature of various cations on zeolite activity may represent, at least in part, a physical effect rather than a variation in intrinsic chemical reactivity.

The diffusion characteristics of sodium mordenite have been studied in a doctoral thesis by William G. Margetts, also under the supervision of Professor Satterfield, using such sorbates as n-butane, n-butene, methane, krypton, and sulfur hexafluoride, at temperatures of 25° to 200°C and the partial pressure range of 1 to 30 millimeters Hg. These various vapors have been chosen for such characteristics as their interaction energy with a solid or their particular molecular shape. The diffusivity relationships are highly complicated and do not follow a simple Fick's law type equation. However, the diffusion characteristics are consistent with a parallel path model representing a rapid rate of diffusion into extra-zeolitic larger pores as well as a simultaneous slower diffusion into the smaller pores of the basic zeolitic structure.

Professor Robert C. Reid has continued his research activity in cryogenic chemistry and has concentrated on elucidating the mechanism of
reactions between hydrogen atoms and solid, thin olefin films at 77°K. There have been several physico-chemical models proposed in the literature. They may be polarized into two points of view: (a) All reaction occurs at the gas-solid interface and the rate of reaction is controlled by the diffusion of olefin from the bulk of the film to the surface; hydrogen atoms do not penetrate the film. (b) All reaction occurs in the bulk of the film; hydrogen atoms do diffuse into the film, and olefins and olefin radicals are essentially immobile when movement over more than a few molecular diameters is considered.

Data taken over the past year have shown that there is hydrogen atom diffusion into the solid hydrocarbon. The experiments have given a value of the hydrogen atom permeation coefficient (the product of the hydrogen diffusivity and the Henry's law constant for hydrogen in hydrocarbon films) of about $10^{-6}$ cm$^2$/sec. This value was found by employing a smooth MoO$_3$ layer covered by the hydrocarbon film. Hydrogen atoms diffusing through the hydrocarbon reduced the oxide and the progressive color change from yellow to blue was a measure of the degree of reaction, that is to say, the total flux of hydrogen atoms penetrating the solid. Also, this colorimetric technique showed that the deposited films of hydrocarbons were smooth, dense films and not porous as a frost might be. Monochromatic light intensities, reflected from the surface during deposition, were oscillatory due to constructive and destructive interference. The surface irregularities of the frost were thus shown to be less than the wavelength of the incident light, 0.6 μ.

Reaction rates between hydrogen atoms and olefins were measured using propylene, 3-methylbutene-1 and methylacetylene. In a number of experiments the olefin was diluted with inert paraffins. Butane and 3-methylpentane were used as diluents. The propylene-hydrogen atom reaction was investigated at temperatures ranging from 77° to 87°K. The olefin was deposited as a thin film in the resonance cavity of an ESR (electron spin resonance) spectrometer. Hydrogen atoms produced by a 2450 MHz (megahertz) microwave discharge were allowed to contact and react with the olefin film. ESR spectroscopy was used to measure the concentration of atomic hydrogen during the reaction.

The products of the reaction between propylene and atomic hydrogen were propane and 2,3-dimethylbutane. The ratio of propane to 2,3-dimethylbutane was constant under widely different average concentrations of atomic hydrogen in the reactor system. The product distribution and the constancy of the distribution under different reacting conditions may be explained by the following sequence of reactions:
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\[
\begin{align*}
\text{CH}_3 \cdot \text{CH} &= \text{CH}_2 + \text{H}^\cdot_{(\text{gas})} \quad \text{CH}_3 \cdot \text{CH} - \text{CH}_3 \\
2 \text{CH}_3 \cdot \text{CH} \cdot \text{CH}_3 &\xrightarrow{k_1} \text{CH}_3 \cdot \text{CH} \cdot \text{CH}_3 + \text{CH}_3 \cdot \text{CH} = \text{CH}_2 \\
2 \text{CH}_3 \cdot \text{CH} \cdot \text{CH}_3 &\xrightarrow{k_2} \text{CH}_3 \cdot \text{CH} \cdot \text{CH} \cdot \text{CH}_3
\end{align*}
\]

The data were best interpreted by assuming that hydrogen atoms diffuse throughout the solid substrate at a relatively fast rate and react with the olefin present in the bulk of the film. The rates of hydrogen consumption obtained from the mathematical model of the process just described were compared with the experimental rates of hydrogen consumption. The best fit between the calculated and the experimental rates was obtained with a hydrogen diffusivity of $1.5 \times 10^{-2} \text{ cm}^2/\text{sec}$ and a reaction rate constant $k_1$ of $7 \times 10^7 \text{ cm}^3/\text{mole-sec}$.

The experimental data obtained from the reaction between atomic hydrogen and the other two olefins investigated, 3-methylbutene-1 and methylacetylene, indicate that these olefins react with atomic hydrogen by a similar physico-chemical process.

Work is continuing with butenes and with a more refined experimental technique that we hope will allow one to monitor both the concentration of hydrogen atoms and olefin radicals during an actual reaction.

Professors Baddour and Michael Modell are continuing their study of fundamental surface phenomena which occur in catalysis by metals. A technique has been developed for determining reaction mechanisms by observing simultaneously the over-all reaction rate and the concentrations of surface intermediates as functions of temperature and reactant partial pressures. Infrared spectroscopy of the surface is used to measure surface concentrations. Postulated mechanisms are tested directly by comparing experimental and theoretical forms of the rate, expressed in terms of surface concentrations. This method, which was used to study the oxidation of carbon monoxide on palladium, is being used to study the same reaction on platinum and other transition metal catalysts. By employing this method for the same reaction on a series of transition metal catalysts, it may be possible to isolate those parameters of the catalyst which are responsible for the observed similarities and differences.

In theory, infrared spectroscopy of surfaces can be used to determine the structure and concentrations of all species adsorbed on a catalyst. In practice, however, there are experimental limitations that have yet to be overcome. In metal catalysis, the most serious limitation is the inability to observe absorption bands for all surface species. Infrared spectra are measured conventionally by transmission spectroscopy of finely dispersed
metal particles supported on catalytically inert alumina or silica particles. Because the supports are opaque to broad regions of the infrared, the absorption bands of adsorbed species heretofore observed have been limited to the 2-to-8μ region. Consequently, only a limited number (if any) of normal vibrations of a given surface species are observed. Thus, numerous disagreements have developed with regard to interpretation of surface structures. In an attempt to resolve these disagreements and to extend the utility of infrared surface spectra, the reflection spectra of species adsorbed on unsupported metal foils are being studied. It was estimated that 50 to 100 sequential reflections are required to obtain quantitative spectra down to one per cent of a monolayer. An interferometer spectrometer is being used to measure the relatively weak signals which are obtained. In this manner, it is possible to scan the region of 2.5 to 40μ. The program is now entering the experimental stage.

Two studies recently initiated are aimed at correlating and understanding the interactions of gases with metal surfaces in the chemisorption process. The kinetics of chemisorption and desorption of several gases on a series of transition metals will be studied with the recently developed technique of temperature programmed desorption spectra. In this manner, it should be possible to distinguish between the rates of adsorption and desorption of each of the several types of adsorbed species which are formed when a given gas interacts with a given metal. In a second study, the rates of adsorption and desorption of hydrogen and deuterium will be investigated on the same metal. Kinetic measurements of the H2–D2 exchange reaction will also be made in an attempt to determine which of the three observed forms of adsorbed hydrogen is more reactive.

Professors Baddour and Modell are continuing the study of the effect of visible and ultraviolet light on gas-phase, metal-catalyzed reactions. In earlier studies, it was demonstrated that light has an appreciable effect on the rate of carbon monoxide oxidation over a palladium catalyst. The effect was attributed to electronic excitation of a surface-adsorbate bond which, in turn, results in a change in the rate of desorption of surface species. The objectives of a study recently initiated are to determine the extent to which other systems can be similarly affected, and to investigate more thoroughly the mechanism of the photocatalysis. Monochromatic light of variable frequency will be employed to determine which frequencies are photoactive. The study should provide information on the electronic structure of the bond between the adsorbed molecules and the surface atoms which can be used to interpret and predict the behavior of metal catalysts.

Professors Baddour and Max C. Deibert have investigated the influence
of the interphase electronic interaction between the catalyst and the support. The catalyst under investigation is nickel supported on germanium. In this system the magnitude of the Volta potential difference and specific interphase charge transfer can be predicted using the Schottky analysis of metal-semiconductor contact. The variations in these parameters, brought about by changes in the type and concentration of impurities in the germanium, have been shown to influence the kinetics of formic acid decomposition on the supported nickel. Additional measurements are being made to determine if the kinetics of cyclopropane hydrogenolysis on the nickel catalyst is similarly influenced by support-catalyst electronic interaction effects. Measurements of total surface area and specific nickel surface area are being utilized to provide a more complete characterization of the nickel-germanium catalyst system. As a part of this research the thermal stability and adsorptive properties of high surface area, vacuum crushed germanium have been determined. Germanium powders with surface areas on the order of 100 square centimeters per gram suffer about a ten per cent loss in area by sintering under vacuum at 300°C for one hour. Neither the freshly crushed nor the sintered germanium powder absorbs measurable quantities of carbon monoxide.

The kinetics of cyclopropane hydrogenation on a pure nickel powder catalyst has been studied to reveal those conditions of reaction composition and temperature in which the activity of the catalyst is most stable. It has been found that the activity of the nickel catalyst at 65°C remained relatively constant in a reaction stream in which the ratio of cyclopropane to hydrogen pressure is below one-third. The rate of catalyst deactivation increases in proportion to the cyclopropane content of the reactant stream above this amount. The activity of a deactivated catalyst can be essentially completely recovered by treating the nickel powder at 350°C, first under vacuum and then under a hydrogen atmosphere. These results provide essential criteria for the study of the kinetic properties of the germanium supported nickel catalysts used in the study of the promoting effect of interphase electronic interaction.

Professor Vieth has studied the rate factors of enzymatic catalysis when a reaction is carried out in a high-shear environment. Calculations have been performed for sucrose hydrolysis on invertase, hydrogen peroxide decomposition on catalase and urea hydrolysis on urease. The calculations indicate that, if either chemical transformation or product desorption has at least a modest energy barrier, rate enhancement in a shear field would be predicted for each system, if even a minute fraction of the eddies in the shear field are of a characteristic dimension in a range approaching that of the heterophase enzyme molecules, and if the
shear field may be considered as locally isotropic. A baffled, well stirred reactor system employing a high-speed impeller has been constructed, with an external recirculation loop passing through a polarimeter cell. Rates of sucrose hydrolysis on invertase are under study, as functions of specific agitation power and kinematic viscosity, with initial attempts aimed at replication of the data obtained in a preliminary study.

Professors Freeman and Baddour are investigating the physical and chemical principles of a high-frequency ozonizer discharge, in the virtually unexplored megahertz frequency regime. Positive ions should remain in the gap between poles leading to substantial modification of the operating characteristics from those of a low-frequency conventional ozonizer. The formation of ozone has been studied at various power levels and pressures and found to exhibit regular though unexpected behavior. The power density in such a reactor is several orders of magnitude higher than that for the same ozonizer operated at 60 hertz. It was found that current pulses were involved and determinations were made of the number of pulses per second, the number of electrons per pulse, the breakdown and cutoff voltages for each pulse. Takaaki Aiba has developed a theory to express the non-uniform electric field as a function of position and the minimum field required for efficient ion production.

Daniel L. Flamm is studying the oxidation of hydrogen chloride in the diffusion controlled glow discharge as well as at low frequency beyond the oscillation amplitude limit. The study later will be extended to ozone production. The work on hydrogen chloride will cover pressures from 5 to 200 torr. A high Q helical resonator has been constructed and voltages well in excess of 20,000 are easily imposed across a parallel electrode quartz cell. Thus a wide range of the controlling parameter E/P, \( \omega / \nu_c \) and \( \omega d \), where \( E \) is the electric field strength, \( \omega \), the driving frequency, \( \nu_c \), the electron collision frequency and \( d \), the discharge gap, can be studied. Beyond oscillation amplitude the plasma voltage drop increases as expected, and the current has been found to flow in pulses of about 30 nanoseconds length independent of the driving force frequency. This indicates that mobility controlled electron transit time determines transition to an ozonizer-type discharge. The highly transient field distribution in this regime is not known, but direct electron temperature probe measurement will be attempted. The chemical results should be comparable with those obtained in the diffusion regime and estimated from a uniform field-pulse number model of oscillation amplitude.

Work is continuing in the microwave arc/glow discharge. Kenton A. Griffis has definitely established a large synergistic effect by sulfur dioxide in the oxidation of nitrogen to nitric oxide with oxygen. An experimental
program is in progress to elucidate the mechanism of this reaction and it is believed that some perturbation of the electron energy distribution is involved.

Professor Edwin R. Gilliland and Lee P. McMaster are investigating catalysis by ion exchange resins and the use of such catalysts to evaluate the performance characteristics of liquid phase packed bed chemical reactors. A modified spherical ion exchange resin was used to study the kinetics of an acid catalyzed reaction. This modified resin was a composite solid consisting of a catalytically inactive unsulfonated inner core and a catalytically active sulfonated outer shell. The reversible esterification/hydrolysis of methanol-acetic acid was used as the model reaction to develop a kinetic expression to evaluate the behavior of the ion exchange resin catalyst under intrinsic kinetics conditions and to study its behavior under conditions of mass transfer limitations.

By using the ion exchange resin catalyst in a packed bed configuration in a kinetically well defined region, the simultaneous measurement of chemical conversion and residence time distribution allows a comparison of the experimental data with various proposed models for contacting in packed beds.

Various two-phase fluidization models are being evaluated using data taken in a two-inch diameter fluidized reactor by Professor Gilliland and Christian W. Knudsen. The model reaction used in the experiments was ethylene hydrogenation catalyzed by copper impregnated fluid cracking catalyst. Reactor operating variables were studied in the following ranges: (1) superficial gas velocities up to two feet per second; (2) bed heights (quiescent) from three-quarters to three feet; (3) catalyst particle sizes (three narrow cuts, one representative mixture) from 44 to 149 microns. Reaction kinetics were first order in hydrogen and zero order in ethylene. Catalyst activity was varied by operating at temperatures of 105°C, 125°C and 145°C and the activities were determined in a small fixed bed reactor from samples transferred from the fluid bed reactor.

CHEMISTRY AND PHYSICS OF POLYMERS AND SURFACES

Investigation of viscoelastic behavior of biocolloid-like complex coacervate systems continues under the supervision of Professors Herman P. Meissner and Hoffman. Two different reaction products of oppositely charged polyelectrolytes are being studied. The swelling of such materials in salt solutions (for example, NaCl, NaBr, NaI) reveals the increased significance of ion-binding of the halide ion to the quaternary polyion in the series iodide, bromide and chloride. The salt and water contents of swollen films are being measured in these solutions. Mecha-
cal studies of creep and stress-strain behavior of the coacervates immersed in these same salt solutions has led to attempts to correlate and predict the modulus as well as the viscoelastic response based on the swelling data. In a new study recently initiated, the polyelectrolytes are being synthesized from the monomers; the charge density in the backbone is being varied in a controlled fashion by copolymerizing with a non-charged monomer. Measurement of swelling data in these systems will also permit a revision and refinement of the equilibrium thermodynamic theory of complex coacervation.

The phenomenon of dilatancy (reversible shear hardening) has been investigated in aqueous kaolinite suspensions in a program directed by Dr. Alan S. Michaels and Professor Hoffman. The critical shear rate for onset of dilatancy was correlated with the solids volume concentration, particle size and shape, and sedimentation rate of the suspension in a centrifuge. The degree of dilatancy is estimated by the slope of a plot of log (shear stress) versus log (shear rate) above the region where dilatancy begins. This also is found to correlate with the parameters noted above. Electron microscope photomicrographs provide a measure of the actual particle size and shape. Prediction of the dilatant behavior of synthetic mixtures of different particle fractions is possible on the basis of the theory developed.

The investigation of the unusual temporary effects of intense radiation fields on the mechanical properties of polymers is continuing under the supervision of Professors Hoffman and Gilliland. The study of the accelerated creep rate of polystyrene samples in a 3-MeV electron beam resulted in the hypothesis of a mechanism based on temporary accumulation of gases within the polymer during irradiation. Extension of the work to polymethyl methacrylate (PMMA) has led to a revised mechanism, wherein the act of gas generation supplies the necessary energy and local free volume to a particular chain segment. Then when the radiation is terminated, these gases diffuse to local voids or fissures, where they are ineffective in accelerating creep further. This mechanism is being tested with polycarbonate polymer films. It has been found that the critical factor governing the rate of creep during irradiation is the state of strain of the polymer, particularly at higher stresses or higher radiation intensities. At very low stresses or low intensities, the total accumulated dose appears to be the most important factor. A modified Eyring relaxation flow theory correlates most of these data.

The research program on structure-property relationships for membrane permeation, under the supervision of Professor Vieth, has progressed through several stages: completion of a doctoral thesis on gas
transport in polypropylene; continuation of research on thermomechanical modification of the polymeric glass, polyethylene terephthalate; initiation of two new programs investigating the transport behavior of strongly plasticized systems, through studies of polymer-water interactions in polyurethanes; and, finally, initiation of a new program to study the morphology of high-impact strength, stiff-chained glassy polymers, such as polycarbonate resins.

A model has been developed for the defect-morphology of semicrystalline polypropylene and the extension of the time-temperature superposition principle for viscoelastic response to a time-temperature-excess volume principle is strongly suggested by the work on polyethylene terephthalate. Permeation and sorption studies of the polyurethane matrix suggest a dual mode sorption model mechanism for water transport through these membranes. Further development of this model should give a better insight into the problem of diffusion in a microheterogeneous medium with simultaneous penetrant localization. Infrared studies are being used to probe for the locus of the water-binding sites. Abnormally high microvoid saturation limits for the polycarbonate resins was observed in high pressure sorption studies and suggests that the high-impact strength of the material is due to the relative ease of viscous energy dissipation.

HEAT, MASS AND MOMENTUM TRANSFER

Professors Edward W. Merrill, Kenneth A. Smith, and Preetinder S. Virk have, with the support of the Office of Naval Research, continued their studies of the remarkable effects exhibited by very dilute solutions of certain high-molecular-weight polymers. Of prime interest is the fact that turbulent flows of these solutions exert significantly less skin friction than does the solvent alone.

Since the polymers used are random-coiling, it has been hypothesized that the observed effects are manifestations of extensive polymer elongation in the ambient shear field. Indeed, the only available theory predicts that, at the shear rates of interest, the molecules may easily be elongated by as much as a factor of ten relative to their unperturbed dimensions. A careful light-scattering study just completed by F. Richard Cottrell has demonstrated that such is not the case, but rather that the extension amounts to only about 30 per cent. Those hypotheses which require extensive elongation are, therefore, invalid and attention is now focussed upon mechanisms related to viscoelasticity effects.

In a related study, Makato Ohara has shown that certain of these solutions undergo laminar-to-turbulent transition via a mechanism
which is quite different from the usual one. Specifically, pipe flows usually exhibit intermittency at transition, but these solutions do not if they are of that class which is drag-reducing at the transition Reynolds number. If drag reduction occurs only for Reynolds numbers significantly greater than the transition Reynolds number, transition itself is conventional.

Much of the information gathered to date indicates that the phenomenon is most pronounced in a region within 150 microns of the pipe wall. Consequently, methods are being developed to permit detailed examination of this region. Drag reduction has also been studied in rough pipes; relative to pure solvent, the fractional drag reduction in rough pipes is significantly greater than in smooth pipes at corresponding flow conditions.

Professor Virk has also studied the high strain rate stagnation phenomena in dilute polymer solutions. Stagnation pressures recorded by small diameter impact tubes are being measured in several homologous polyethylene oxide solutions to ascertain the net energy discrepancy with respect to Bernoulli's relation. Also, local and over-all heat transfer coefficients from small cylinders in cross flow are being determined. The object of these measurements is to ascertain the flow structure for a simple configuration (stagnation flow) and relate it to the properties of the macromolecular solutions. High Schmidt number mass transfer studies indicate that, during the Toms Phenomenon, turbulent mass transport near a wall can be reduced considerably more than the momentum transport.

Professors Brian and Reid have continued their investigation of the properties of water frosts formed at low temperatures. Humidified nitrogen gas deposited a frost while flowing over a short copper plate maintained at 77°K. Frost thickness, density, and thermal conductivities were measured as a function of time for various runs in which the gas-phase Reynolds number, temperature, and humidity were varied. Temperature profiles within the thin frost layers were also determined.

It was found, as expected, that the frost density and thickness increased with time during a run. More interesting, the heat flux became constant even though the frost thickness continued to increase. The constant heat fluxes implied a constant frost surface temperature and, indeed, experimental measurements verified this assumption.

The fact that the frost surface temperature varied only slightly over a wide range of experimental conditions suggests the presence of a high-gain feedback effect tending to keep it constant and confirms the suspicion that the compensating effects which result in a steady state heat
transfer rate are by no means compensating simply by chance. The rate of internal diffusion of water vapor within the frost layer is a strong function of frost temperature. The partial pressure gradient which forces the water vapor diffusion can be thought of as the product of a temperature gradient and the slope of the curve of water vapor pressure versus temperature. This latter quantity increases exponentially as the frost temperature increases, and thus the importance of water vapor diffusion in the frost layer is strongly dependent upon temperature level. As the insulating frost layer builds up on the cold plate, the heat flux decreases and the frost surface temperature rises. Finally, however, the frost surface temperature reaches a value at which internal water vapor diffusion within the frost layer becomes very substantial, and the frost layer begins to densify. As more frost accumulates and the frost layer gets thicker, there is a tendency for the frost layer to insulate the surface even more, causing a further increase in the frost surface temperature. But because of the very high sensitivity of internal diffusion to the frost surface temperature, a very small increase in the surface temperature results in a sufficiently great increase in the rate of diffusion of water vapor that the thermal conductivity and density of the frost layer are increased to the point at which the heat flux falls off only very slightly and the surface temperature rises only very slightly as additional frost is deposited. Thus the frost surface temperature and the heat transfer rate are stabilized by a very high-gain negative feedback effect of frost surface temperature upon the rate of densification of the frost layer. Since the frost surface temperature will vary only a little, the thermal resistance of the frost layer is automatically adjusted to be in a given ratio with the thermal resistance of the gas phase boundary layer. For example, increasing the gas phase Reynolds number decreases the thermal resistance of the gas phase and thus forces the frost to become denser in order that it too will have a decreased thermal resistance. This is exactly the effect of gas phase Reynolds number upon frost density which has been observed. Experiments are in progress to test many other effects predicted by the model and a computer program has been written to facilitate such predictions.

During the past year Professors Brian and Samuel W. Bodman III have continued their investigation of heat transfer accompanied by a simultaneous reversible chemical reaction. Experimental measurements have been made of the thermal conductivity of decomposing nitrogen dioxide at temperatures of 700° to 900°K and pressures up to 30 atmospheres. The experimental results are compared with those already available for heat transfer to a turbulent, reacting gas. It is hoped that this
comparison will elucidate the interactions of energy transport and chemical reaction in a turbulent field.

Professors Evans and Reid have continued their studies of natural convection circulation in enclosed fluids. The recent work dealt with a constant heat flux imposed on two sidewalls of a rectangular container. The purpose of the study was to gain an understanding of the fluid dynamics and temperature fields in the fluid for a wide range of system parameters. Such knowledge is required for determining system properties such as the vapor pressure and maximum temperature in vessels as well as offering design criteria for altering the temperature fields for particular applications. It was shown that the fluid behavior is dependent on three dimensionless groups: the Modified Rayleigh Number, the Prandtl Number, and the Aspect Ratio. In the present work, the Modified Rayleigh Number was varied from $10^6$ to $10^{13}$, the Prandtl Number from 7 to 12,000, and the Aspect Ratio from 1 to 3. Velocity measurements were made by taking time exposure photographs of aluminum-coated polystyrene beads dispersed in the test fluid. Knowing the length and orientation of the resulting streaks, the magnification of the photograph, and the exposure time, stream functions as a function of time could be determined. The temperature fields were determined by recording the output from 34 thermocouples.

It was found that fluid moves up the wall in a boundary layer. The thickness of the layer diminishes as an axial thermal gradient is established in the core of the fluid. This gradient is linear with axial distance and increases with time. However, there is no perceptible horizontal gradient except in the boundary layer region. Once an axial gradient is established, two main flow regimes seem to form. One is a surface-influenced flow where the boundary layer fluid is deflected horizontally at the surface, thereby displacing the cooler fluid downward in the core. The other is a core temperature-influenced flow, where boundary layer fluid separates from the wall and moves into the core because of the core temperature gradient.

Professors Vivian and Brian are continuing their research in simultaneous gas absorption and chemical reaction. One study is concerned with the effect of a diffusional resistance upon the product distribution in sequential gas-liquid reactions. Many important chemical reactions involve the absorption of a gas into the liquid phase in which the chemical reaction takes place. Often, several competing chemical reactions occur. Examples are the liquid phase chlorination of hydrocarbons and liquid phase oxidation of organic compounds. In such situations, if the kinetic rate of the reaction is quite rapid relative to diffusion rates within
the liquid phase boundary layer, steep concentration gradients are required for the reacting species to diffuse together, and the chemical reaction takes place in a zone in which the reactants are severely depleted. But this is where the products of the chemical reaction are generated, and if they in turn react further with the dissolving gas, these diffusional effects result in overreaction. The present study is directed toward a generalization of the theory of mass transfer effects upon selectivity and toward an experimental test of this theory.

Interfacial turbulence which may be induced by the gas absorption process and which was demonstrated by a tracer technique in the studies of the carbon dioxide-monoethanolamine system and the triethylamine system continues to be an important research problem here and elsewhere. Visual observation of this turbulence for stationary interfaces has recently been reported. An experimental and analytical study is currently under way to investigate the quantitative aspects of the phenomena in the case of moving liquid surfaces such as are encountered in chemical process equipment.

Professor Gilliland and John T. Day are investigating the dynamics of spherical particles in flow along a cylinder and in the annular gap between concentric cylinders of which the outside is rotating. The ratio of the particle diameter to the diameter of the tube or to the gap of the Couette apparatus ranges between 0.4–0.98. The study is being conducted in a flow regime where both inertial and viscous forces are important. The tube flow system is being modeled numerically by a finite-difference analog of the Navier-Stokes equation. The object of the study is to gain a better understanding of the flow behavior of suspensions in Couette and Poiseuille flow fields which serve as models for the pipeline flow of slurries, blood flow, settling, filtration and pneumatic conveying phenomena.

William I. Koch, working under the supervision of Professors Baddour and Gilliland, is investigating the flow of helium through microporous plugs of silica. It has been reported in the literature and determined in this work, that helium gas permeation of unconsolidated Vycor glass plugs has a much larger temperature dependence than would be predicted by Knudsen's equation. It has been suggested that this is due to surface flow of adsorbed molecules, but due to the low adsorption of helium on silica over most of the temperature range this does not appear to be a logical explanation. Results have been obtained on pressed plugs of Cab-O-Sil and these give good agreement with the Knudsen relation over a broad range of temperature and pressure.
In the area of blood rheology, collaboration with outside institutions has extended to include, during the past year, the Deaconess Hospital, Boston (Dr. Baladimos, studying diabetes and hyperlipemia), the Medical School of the University of Rochester (Dr. Robert Weed, studying cell metabolism), the United States Medical Research Institute, Bethesda, Maryland (Dr. David Moss, studying effects of surgical procedures on blood), and the Walter Reed Army Medical Center, Washington, D.C. (Dr. M. Bernadette Garvey, studying the effect of hyperbaric conditions on the viscosity of blood).

In a joint program with the Department of Connective Tissue Research of the Retina Foundation, Boston, its Director, Dr. Andre Balazs, Professor Merrill, Dr. David Gibbs (Dewey and Almy Chemical Company), and Dr. Nils Rydell (Gothenberg, Sweden) have continued studies on the viscoelastic properties of synovial fluid, with a view to understanding its lubricating function in joints. This has necessitated adapting the GDM Viscometer, made available to the Department of Chemical Engineering through the M.I.T. Instrumentation Laboratory, for testing very small samples (0.2cc) of synovial fluid, taken from human donors. It is a tribute to the Instrumentation Laboratory's design of this device that this modification has proved to be entirely feasible and testing on these small quantities of fluid is now being carried out routinely.

Closely related to the above study of real synovial fluid is a program of fundamental investigation on one of its principal macromolecular components: hyaluronic acid. Ross A. Odell will be studying the interrelationship of light-scattering, intrinsic viscometry, gradient dependence of viscometry, and the viscoelastic properties of hyaluronic acid in solutions of physiological relevance.

In the area of biomaterials, Professor Merrill, Dr. Edwin Salzman of the Beth Israel Hospital, Dr. W. Gerald Austen of the Massachusetts General Hospital, and a research team in the Department of Chemical Engineering have been actively engaged in the investigation of heparinized cellophane, with respect to its possible application to biomedical devices such as the artificial kidney machine.

Dr. Patrick S. L. Wong and Professor Merrill have synthesized a biomedical material of great potential interest—a hydrogel containing covalently bonded heparin. This material can be prepared in the form of membranes, tubing, valves, and other configurations of medical and surgical interest, and has the property of preventing the coagulation of blood brought into contact with it without requiring, as some other materials do, the diffusion of heparin into blood. In vivo animal experi-
ments are now under way to investigate in detail the potential of this material for extracorporeal and intracorporeal devices and prostheses.

Professors Merrill, Smith and Evans have also been active in investigating the engineering problems associated with the artificial kidney. Clark K. Colton, working under their direction, has developed a new technique for the determination of membrane permeability. This method provides a better evaluation of the fluid resistance to mass transfer and hence an improved estimate of the true membrane resistance. Furthermore, the method is less time-consuming than those used previously. The data thus generated is now being applied in a study of the behavior of a single module of an artificial kidney. Arun N. Dravid is now undertaking a study of mass transfer in helical coils. By virtue of the induced secondary flow, a helical coil presents less tube-side resistance to transfer than does the corresponding straight tube. This, then, could lead to artificial lungs and kidneys which are considerably more compact than those used at present.

The swelling behavior and viscoelastic properties of elastin are being investigated in various polar organic or aqueous salt solutions. This project is headed by Professor Hoffman. Elastin is a major component of the blood vessels (such as the aorta) and ligaments in the body. Its structure is still not well known and it is hoped that these studies will aid in a better understanding of elastin structure and its effects on aging and arteriosclerosis. Elastin behaves as a cross-linked non-polar rubber, and estimates of the average molecular weight between crosslinks, $M_c$, are obtained from the viscoelastic data. It has been found that purified elastin samples exhibit increased $M_c$ values in a polar organic solvent such as formamide, or in mixtures of formamide and water. However, when these solvent systems are exchanged with water and the $M_c$ remeasured in water, there is a marked irreversibility noted for the $M_c$ values of those samples previously in 25 per cent and 50 per cent formamide/water solutions, while the samples previously in 75 per cent and 100 per cent formamide/water solutions display almost complete return of $M_c$ to the lower values noted in water. Aqueous sodium iodide solutions also cause a sharp rise in $M_c$ at as low a concentration as 0.1 per cent NaI (1,000 parts per million), and this effect is irreversible; that is to say, $M_c$ values remain high even after leaching out the NaI. These and other studies will be interpreted in terms of a molecular model of natural elastin. Drs. Carl Franzblau and Marott F. Sinex of the Boston University Medical Research Center, well known for their work on elastin, have been invaluable in their assistance to this project.
Professors Hoffman and Modell are investigating the preparation and properties of new membranes prepared by terpolymerizing or tetrapolymerizing various acrylic monomers, in order to develop new and useful reverse osmosis desalination membranes. The membranes first are characterized by their salt and water contents as a function of salt concentration in solution. Following this, their reverse osmosis performance is studied. The results are interpreted in terms of a model that depicts two water transport mechanisms: primary H-bonded water free of salt and secondary water associated with salt ions. From this analysis, predictions have been made as to how composition should be changed to obtain improved flux and permeability to water, and these predictions have just recently been verified experimentally. Some of the membranes developed are better in performance (flux and salt rejection) than dense, homogeneous cellulose acetate, and work is in progress to polymerize the best monomer compositions in thin layers on porous supports.

During the past year, research on membrane desalination has been carried out under the supervision of Professors Vieth and Douglas with the assistance of Dr. Rene Bloch. Investigations of the synthesis and transport properties of two membrane systems have been completed. These systems comprise non-crosslinked copolymers made from hydroxyethyl methacrylate (HEMA) and ethyl methacrylate (EMA) and membranes made from polyurethanes. The objectives of the current research have been to investigate the nature of the membrane-penetrant interactions and, using this information, to optimize membrane performance. The studies have shown that both of the materials have promise as reverse osmosis membranes.

The studies of HEMA-EMA copolymers have shown that it is possible to control the permeability of the film by varying the monomer ratio. Water and salt flux were calculated from the results of osmosis experiments and were somewhat lower than the values for cellulose acetate. The mobility of water varies by several orders of magnitude between a high-flux cellulose acetate membrane and a low-flux HEMA-EMA membrane. The more hydrophilic polymers have the higher water transport as well as the higher salt flux, and the optimum membrane composition appears to be achieved at a 5/2 ratio of HEMA/EMA.

Solution-cast and bulk-polymerized membranes of pure HEMA, despite their close chemical similarity, behave differently, demonstrating the importance of physical parameters of the membrane. The preparation of stable asymmetric membranes of HEMA-EMA copolymers did not succeed, as these materials show considerably greater compaction than
cellulose acetate. Porous structures were achieved but collapsed over
periods of hours when exposed to high pressure.

The study of polyurethanes has led to the development of moderate
flux, moderate rejection membranes. The data obtained show that the
water flux at constant applied pressure increases more rapidly with de-
creasing brine concentration than could be accounted for by the change
in potential. In addition, the salt flux with a 1 per cent solution was
higher than would be predicted on the basis of extrapolation of the data
obtained at a concentration of 4 per cent. This suggests that the tight-
ness of the membrane structure depends strongly on the water activity in
the solution with which the membrane is in contact. Thus, increasing
water activity (lower salt content) apparently causes loosening of the
structure. This in turn indicates that the primary mechanism responsible
for membrane structural integrity is interchain hydrogen bonding. In an
effort to confirm these hypotheses, attempts have been made to charac-
terize the membrane in ways other than those employing reverse osmosis
testing alone. Reverse-osmotic water permeabilities, equilibrium water
sorption levels, and rates of approach to sorption equilibrium were mea-
sured for a series of polymers, including hydroxyethyl methacrylate,
copolymers of HEMA and ethyl methacrylate, cellulose acetate, cellulose
nitrate and polyurethanes. Pronounced equilibrium solvent clustering
behavior was observed for these systems as vapor saturation was ap-
proached in sorption experiments.

Professors Sherwood, Brian, Sarofim and Smith are studying a number
of aspects of the production of fresh water from sea water by the freezing
process, under a grant from the Office of Saline Water. Freezing processes
appear to be competitive with distillation plants, especially for pro-
duction capacities in the range of 200,000 to 3,000,000 gallons per day.
The technology of the distillation process, however, is much further
developed.

Research activities in this area have been concentrated on the better
understanding of the phenomena basic to the design and operation of the
crystallizers in which the ice is produced, the wash column in which the
ice and brine are separated, and the melter in which ice is melted to
produce potable water. The earlier studies of concentration polarization
in reverse osmosis are found to be relevant to the similar phenomena
encountered as ice crystals grow in brine. A continuous well-stirred
crystallizer for freezing saline solutions by direct contact with evaporat-
ing isobutylene droplets has been constructed by Geoffrey Margolis. The
rates of nucleation and growth of ice crystals are being measured under
conditions that approximate those encountered in industry. Crystal size
and size distribution of the ice in the slurry leaving the crystallizer are obtained from photographs of the flowing slurry and from permeability measurements on a packed bed formed by a representative sample of the slurry. A fourfold variation in ice bed permeability has been observed for runs made under a wide range of residence times, weight per cent ice production, and refrigerant temperature. It is the permeability of the ice bed formed from the slurry that largely determines the size and cost of the washing equipment. The results imply that the operation of a wash column may be influenced greatly by changes in the design and operation of a crystallizer and by the method of formation of the ice bed.

In a parallel investigation Shantaram G. Kane is studying the mechanism of nucleation and growth by making a cinematographic record of the surface of a single crystal suspended in a crystallizer from the tip of a wire.

Much of the literature suggests that the ice particles formed by crystallization from a solution are single crystals. The rate of growth of the original small nuclei is believed to be limited at the outset by the kinetics of crystal growth but later, as the size increases, by mass and heat transfer from the crystal to the ambient solution. However, some of the evidence obtained recently by Mr. Margolis and others suggests that the particles whose sizes determine the permeability of the bed of ice in the wash column may be clumps of very small crystals which have agglomerated in the crystallizer. No conclusion as to the validity of this hypothesis is yet possible, but if shown to be true, the whole approach in studies of freezing to produce washable ice will have to be redirected. It could mean that the technological problem hinges on the mechanism of agglomeration and the leaching of clumps of many crystals, rather than on the growth of single crystals.

A study of the problem of removing the adhering brine from the masses of ice particles has just been completed by David L. Ritter. A small pilot plant in which ice was produced from a salt solution and the ice brine slurry fed to the bottom of a vertical column was built and operated. Chilled de-salted water is fed to the top; brine is removed at an intermediate point and compacted well-washed ice is removed from the top. A small amount of a soluble inorganic tracer is added to the wash water in order to obtain accurate measurements of the loss of fresh water in the discarded brine. The dynamics of the column depends on the forces acting and particularly on the wall shear stress. Similarly, the washing efficiency depends on the dispersion process in the top of the column. Models have been developed for both of these processes and the ability to scale-up small columns is now believed to be much improved.
In the melter-condensers used in the freezing process ice is melted by direct contact with a somewhat warmer condensible vapor. The vapor may be either water or that of an immiscible organic refrigerant. In this way, significant heat economies can be effected. The vapor flows directly into the porous ice mass and condenses with concomitant ice melting. An analysis has shown that the rate is severely limited by bed resistance to vapor flow. Larry W. Petri has confirmed this prediction in some preliminary experiments and is now embarking on a more detailed investigation. Water vapor condensation on ice occurs at absolute pressures of 5 to 8mm Hg, and accurate measurements of the air content of the vapor are necessary, since the condensation rate is seriously reduced if non-condensible gases accumulate at the ice surface.

Hugh B. Hales' study of heat and mass transfer to particles suspended in an agitated liquid, described in the report of a year ago, is the subject of two papers to be published in the American Institute of Chemical Engineers' *A.I.Ch.E. Journal*. As in the cases of several other of the desalination studies, the results have application in a variety of other fields.

**ELECTROCHEMISTRY**

Professors Herman P. Meissner and Deibert are conducting studies on the operating characteristics of fuel-cell electrode systems. Studies have been made of the relative effectiveness of the electroreduction of dissolved oxygen, on various portions of cylindrical wires in immersed flow-through electrodes, and on the activation of fuel-cell anodes by natural or induced current pulses in the short circuit direction. The analysis has indicated that the important parameters determining the efficiency of the activations are the electrode-electrolyte capacitance, the maximum potential attained by the anode during the pulse, and the chemical nature of the electrode poisons. The results of experiments on the activation of platinum-catalyzed anodes consuming hydrogen containing 1 per cent carbon monoxide were specifically investigated. Under conditions in which natural oscillations of the potential of this anode occur at constant controlled currents, the efficiency of the activation increases at the higher potentials attained at high currents. This results in the interesting observation of an increase in the rate of the anode reaction being accompanied by a decrease in the time average thermodynamic driving force for the reaction.

In other work by Professors Meissner and Deibert, an attempt was made to synthesize ethylene dichloride electrolytically from waste hydrochloric acid, ethylene and oxygen. The operating characteristics of a
chlorine evolution anode over which ethylene is passed has been specifically analyzed. Initial experiments indicate that more than two chlorine atoms were substituted on each ethylene molecule.

Professors Gilliland and Evans have continued their investigation of the rates of ion transfer through a porous membrane when voltage, pressure and concentration differences are imposed across the membrane, and a hydrodynamic flow of electrolyte through the membrane opposes the electrical movement of either cation or anion. Such membranes are useful in industrial processes to carry out chemical reactions or separations in an electrochemical cell. The objective of this work is to obtain a better fundamental understanding of the important parameters which influence the performance of the membrane.

The rates of transfer of each ionic species through an idealized membrane with parallel cylindrical pores has shown that when the boundary layer resistances outside the membrane are eliminated, the rates can be predicted from the physical properties of the electrolyte, the porosity, thickness, and pore-size distribution of the membrane, and the differences in voltage, pressure, and concentration applied across the membrane.

In order to test these predictions, a series of unsteady-state experiments have been carried out in an electrochemical cell in which the two compartments provided with high speed stirrers and separated by a porous membrane have been filled initially with sodium chloride solutions. By measuring the electrolyte concentration in each compartment as a function of time, the rate of transfer of each species across the membrane was determined. Current was supplied to the cell through specially prepared silver-silver chloride electrodes; flow through the membrane was maintained by a continuous feed of electrolyte into one compartment and removal from the opposite compartment. Experiments have been made using a commercially available filtration membrane under conditions of diffusion alone, diffusion with flow, and diffusion with electric current. All of the experimental data are in good agreement with the results of the theoretical analysis.

**COMPUTER STUDIES OF PROCESS DESIGN AND ESTIMATION OF PHYSICAL PROPERTIES OF CHEMICAL COMPOUNDS**

Professor Evans, with the cooperation of Professor Leonard A. Gould of the Department of Electrical Engineering, has investigated the use of optimal control theory to determine operating policies for unsteady-state chemical processes. For process units such as a batch chemical reactor whose normal mode of operation is unsteady-state, the theory
has been applied to determine the optimum variation of temperature, pressure, and concentration throughout a batch cycle. For continuous processes which are normally operated at steady-state, the theory has been applied to determine the best method of start-up, the best program for changing from one operating level to another, and the best method for restoring the process to steady-state after an unexpected upset. Because of the non-linearities inherent in the mathematical models of most chemical processes, solutions to the optimization problem usually must be obtained numerically. A major focus of the research has been upon the development and evaluation of improved computational algorithms for solving the optimization problems.

Professors Evans and Gould are investigating the use of modern time-shared computing systems for computer aided chemical process design. The initial goal of the work is to develop a prototype system which can accept a problem-oriented description of a chemical process and can carry out on command the types of analyses useful in the preliminary stages of chemical process design. These analyses include steady-state heat and material balancing, economic evaluation, and optimization. A systematic attack is being made upon the problems of developing such a computing system. The major problems include representation of an arbitrary chemical process within the computer in a convenient, flexible manner, solution of the large systems of non-linear equations describing the heat and material balances for an interconnected process with recycle streams, and communication with the user. An important objective of the work is to use the prototype system to ascertain the benefits that might be gained in chemical process design from a powerful man-machine combination.

Professors Reid and C. Michael Mohr supervised a research program to automate physical property estimation techniques of the structural increment type. The computer system will be a useful addition to the present A.I.Ch.E. Physical Property Estimation System.

Programs were developed to accept an atom-by-atom description of the compound structure and to generate the group counts for estimating critical properties by the method of Lydersen, and heat capacities, enthalpies and internal energies of ideal gases by the Rihani-Doraiswamy method. The Sussenguth chemical structure-matching algorithm was used for counting the relevant subgroups in the molecule. In tests on 43 compounds, the execution time on an IBM 7094 computer to search the compound structure for 56 common subgroups ranged from 1.07 to 10.33 seconds, depending on the complexity of the molecule. Input/output, program loading, and other overhead times are not included.
SCHOOL OF ENGINEERING

The Sussenguth algorithm, in its present form, was found to be rather inefficient when there were a number of identical groups in the molecule, and it did not correctly match groups containing conjugated or adjacent double bonds.

EDWIN R. GILLILAND

DEPARTMENT OF CIVIL ENGINEERING

In 1963 we devoted our annual report to a statement of our educational and professional philosophy. The essence of this statement was the identification of civil engineering as a set of challenging problems, concerned with the engineering of systems of constructed facilities and requiring inputs from many disciplines. Subsequent reports focused on the five traditional technical divisions (structures, materials, soils, water resources and transportation) which form the administrative substructure of the Department. This year, we have chosen to describe our activities in four problem areas to define more clearly how our current educational and professional concerns coincide with the pressing environmental problems of today's world. The report which follows was prepared by Professor Peter S. Eagleson from inputs provided by many members of the faculty.

ENGINEERING METHODOLOGY

Until relatively recently, efforts to improve the end product of civil engineering have usually followed one of two paths:

1. To upgrade the information available to the engineer by obtaining a deeper understanding of the underlying physical sciences and incorporating this knowledge into improved mathematical models suitable for the analysis and design of individual facilities.

2. To devise better materials and construction methods.

While still necessary, these approaches are no longer sufficient.

The accelerating increase in the mobility and urbanization of the industrialized peoples has had a profound effect on the magnitude, scope and complexity of civil engineering problems and on the attitudes of the users toward the systems of facilities constructed in the solution of these problems. To fulfill his responsibilities, the civil engineer must not only find means to meet the enormous demand for new construction but must also extend his interest beyond the realization of individual structures and into the planning, monitoring, operational control and management of entire systems of facilities. Furthermore, in the whole of this endeavor,
a concerned society demands economy as well as the realistic consideration of the resulting human benefits.

The complexity of the tasks outlined suggests that a third and possibly more immediately profitable path to better civil engineering may lie in improvements to the process by which engineering is performed rather than to the theory on which it is based.

Application of the information sciences, in which digital computer systems are used to bring the power of probability, statistics, mathematical programming, optimization and simulation to bear on the engineering process, offers at least a partial answer. It enables the engineer to search for and evaluate alternative solutions systematically. To this end, much of the Department's research effort over the last few years has gone into the development of a complete system called ICES (Integrated Civil Engineering Computer System), designed to serve as a framework and foundation for computer use by the entire civil engineering profession. The system has two components: the ICES system and the ICES subsystem. The ICES system incorporates advanced computer programming languages and capabilities to perform language translation, data and program structuring, memory allocation and data management. These capabilities present in the ICES system are used to create engineering subsystems and then to run the created subsystems. The relationship between the system and subsystems is thus hierarchical in that the subsystems run under the control of the system and are created using the system.

Each of the subsystems is associated with a particular application area. For example, the STRUDL subsystem of ICES deals with structural analyses and design, while the COGO subsystem deals with geometrics. At present, there are more than 15 ICES subsystems in such areas as highway location and design (ROADS), transportation planning (TRANSIT and TRAVEL), soil engineering (SEPOL and LEASE), project scheduling (PROJECT), bridge design (BRIDGE), optimization techniques (OPTECH), information storage and retrieval (TABLE and ENIS), management and control (DEMAN), hydraulics (HYDRA), and building systems (BUILD and INSITE). The availability and integration of these subsystems allow engineers to achieve complete problem solutions in which all factors and data interactions are properly considered. ICES is designed in a modular expandable fashion so that existing subsystems can be modified and new subsystems can be incorporated. Each engineering organization can choose the subsystem it wishes to use, modify others and add new ones. Thus an organization can generate its own version of ICES based on its problem solving needs.

An engineer communicates with an ICES subsystem using problem
oriented languages which enable him to communicate with the computer easily and effectively, using familiar and convenient terms. The subsystems are intended for use by engineers, not computer professionals.

One of the primary goals of the ICES work is to simplify communication between man and machine. In addition to providing flexible oriented language inputs, the system incorporates graphical output on a variety of devices and enables engineers to communicate with computers from remote locations. Considerable attention has also been directed toward the concept of a computer network in which large and small computers could communicate and share information and work loads. This work has particular pertinence for engineering organizations having small local computers which will communicate with a larger central computer, and for M.I.T., where the various departments and laboratories with small machines can communicate with larger machines at the Information Processing Services Center.

During the past year, the first operation version of ICES was completed for the IBM System/360 computer. The system is now being distributed free of charge by the IBM Program Library and has been ordered by more than 400 organizations. Work on many of the subsystems is continuing and new capabilities are being added.

ICES will have a major impact on the curriculum and teaching of civil engineering as well. The Department is therefore developing appropriate educational material to be used by engineering schools in conjunction with ICES.

Improvements in the analytical and experimental methods of civil engineering are proceeding in parallel with the computer system development. The analytical methods draw upon basic research in materials and mechanics and themselves provide the basis for the ICES subsystems. Some specific examples are in order:

1. The Department has accelerated the evaluation of the performance of actual civil engineering structures. During the past year, field measuring devices have been installed on the following types of structures: (a) braced excavation, (b) breakwater, (c) soft foundations subjected to a heavy load, (d) foundations for a facility to store liquefied natural gas and (e) natural earth slopes. Periodic observations are being made of pore water pressure, vertical movement, horizontal movement, and total stress. Comparisons are being made between predicted and measured performance. The results of these comparisons are being used to evaluate and improve the methods of predicting behavior and for determining parameters for use in these methods.

2. Computerized finite element methods are being developed for the
analysis of structural continua to assist practicing engineers in the design of complex but more efficient structures.

3. Small-scale structural models are being used to study shell-type concrete structures and to investigate the non-linear behavior of steel building frames.

4. More economical structural frameworks and construction methods are being sought for high-rise steel buildings.

5. The use of mathematical programming and optimization methods in the planning for comprehensive development of water resources in river basins or other hydrologic units is being explored.

6. Concepts from information theory are being used to develop generalized criteria for the design and evaluation of hydrologic instruments, networks, and programs for data collection.

7. The utility of laboratory scale models as a tool for the study of urban runoff is being explored.

**TRANSPORTATION SYSTEMS**

The Department's work in transportation systems is concerned primarily with the planning, design and implementation of multi-modal transport facilities. Because of the widespread effects of large-scale networks, our activities require the full range of computer techniques, systems analysis and optimization methods as well as sensitivity to the social, political and economic constraints.

We are involved in the development of a unified theory for transportation system analysis and related operational studies. An integrated set of transportation models of multi-mode systems is being developed and applied to transportation problems at national and urban scales and in developing countries.

We are developing techniques for searching out and choosing among alternative transportation systems and are applying the results to regional transportation in the Northeast Corridor.

Development of techniques for evolutionary planning of transportation and other components of the urban system is under way. Since the urban system is evolving rapidly, sequential, staged strategies are more appropriate than static plans. Determinations of the value of information are being made in order to permit (1) design of optimal information-collection procedures, (2) construction and testing of alternative sequential strategies, and (3) prediction of the impact of analysis results on the political process.

Models are being developed which relate different combinations of the components of a regional transportation system to a number of significant
system performance variables. The study explores ways in which components may be combined to achieve alternative levels of system performance and examines relationships between component costs, system costs and the level of system performance.

Research is exploring heuristic and analytic methods for making routing and scheduling decisions. Attention is being given to how alternative routing and scheduling procedures affect the productivity of large, multimodal systems, and to the effects of random events, including measures of the sensitivity to uncertainty of alternate operating plans.

An information system is being designed to enable transportation planners to maintain optimum routes and schedules. The system will calculate the value of potential items of information, monitor the transportation environment to detect changes as they occur, and reformulate the transportation problem to generate up-to-date optimal solutions.

A computer aided routing system (CARS) is under development. CARS is a mass transportation service offering the desirable characteristics usually associated with automobile travel at a cost commensurate with traditional conventional mass transportation services. By incorporating the latest advances in computer and communication technology, CARS can immediately respond to and service demand requests as they arise. The scheduling and routing of CARS vehicles is coordinated by a digital computer that receives demand requests from people over conventional telephone lines. A person can request service by phoning the computer from his home and registering his desired destination. The computer then will route a vehicle to pick up the customer. The passenger waits in the comfort of his home until that vehicle arrives to collect him at his door. The vehicle then takes him to his destination, possibly stopping on route to pick up or let off other customers.

WATER QUALITY AND POLLUTION CONTROL

The alteration of man's environment through changes in the quality of water has been well documented in both the technical and popular media of information exchange. The public has been aroused, and private, industrial, and government agencies are devoting funds at an increasing rate to the control of water quality. Paralleling the increased funding is the need for increasing the supply of engineers in the field of water quality control.

The traditional dimensions of waterborne wastes have been in the areas of organic and inorganic constituents. Organic wastes cause difficulties because of their pathogenic nature, odor production, and unsightly appearance. Inorganic wastes arise from evaporation, erosion accelerated
by urbanization, and runoffs containing pesticides and fertilizers. It is estimated that the Colorado River Aqueduct delivers one million tons of salt per year—a 70-car trainload per day—to the Southern California coastal plain. Recently, a third dimension has been added—that of thermal pollution caused by the rapid increase in the production of power by fossil fuel and nuclear plants.

Pollution control technology may be divided broadly into three phases:

1. The collection of waste products from their immediate sources and their transport to designated places for treatment and disposal.
2. The treatment process, which may remove certain components or otherwise modify the waste material.
3. The disposal of either the raw or treated waste into the ocean, estuary, river or into the ground.

Pollution control technology is most advanced in the second phase—that is, in the design of treatment plants to accomplish certain levels of purification and removal of undesirable components. This is the traditional concern of sanitary engineering, in which the chemical and biological processes of waste treatment are emphasized.

During the past decade this Department has maintained an increasingly active teaching and research program in the area of water quality and pollution control. The primary objective has been to focus attention on those problems in which fluid flow, mass, and heat transfer processes are important, primarily Phases 1 and 3. At present, only a handful of universities are providing effective training in these two important areas.

Phase 1 — The collection system is an integral part of all urban development. The engineer is faced with the difficult task of piecewise additions to and modifications of existing overburdened sewage and storm water collection systems. The most pressing needs for knowledge and training are in the areas of urban hydrology and in the mechanics of unsteady flow in open channels.

Phase 3 — The disposal system is an interurban problem because of the strong interaction between waterborne effluents from neighboring sources. The most urgent needs are in the application of basic fluid mechanics for the determination of temporal and spatial distributions of water quality parameters. Systems analysis and economic optimization techniques are needed to treat the combined effect of many disposal points of varying quantity of material and degrees of treatment into a river, reservoir, estuary, or coastal area.

The Department is involved in extensive research into Phase 1 and Phase 3 aspects of the water quality problem. Some examples follow:

1. A simulation of surface runoff due to rainfall on urban catchments is
being developed for use in finding an optimum linear representation of
the process which is suitable for use in algorithms for the optimal design
of urban drainage systems.
2. Unsteady flow in networks of open channels is being analyzed numeri-
cally and dynamic programming is being applied to the optimal design of
sewer and drainage systems.
3. Groundwater dispersion in the flow between separate recharge and
pumping wells and between pumping and recharge operations in the
same well at different periods of time is important in the field of ground-
water contamination. An efficient finite difference scheme for the solution
of such (two-dimensional) problems is being sought.
4. Dispersion is being studied in estuary-type flows consisting of an
oscillating flow with a fresh water throughflow superimposed. The simili-
tude of distorted estuary models is being investigated in regard to dis-
tribution of pollutants in the fresh water region of the estuary.
5. Field data on salinity intrusion and diffusion in estuaries are being
analyzed to develop methods of predicting changes in the longitudinal
distribution of salinity due to changes in fresh water flow rate, channel
depth, tidal prism, and other factors. The relation between salinity intru-
sion and shoaling is also being studied.
6. An analytical method is being developed for the prediction of the
vertical temperature distribution, as a function of time, in a lake or pond.
Techniques are being developed for modeling a time-dependent tempera-
ture structure in laboratory tanks using artificial thermal radiation. The
study is being extended to the prediction of the transient temperature
distribution in a reservoir having inflow and outflow.
7. A model study of the mixing of condenser water from the Browns
Ferry Nuclear Power Plant into the Tennessee River is being performed.
The temperature rise is being investigated in the river upstream and
downstream of the plant during steady-state river flows and during pe-
riods of no flow caused by peak-load duration of a downstream hydro-
electric plant.
8. Methods are being developed for the design of skimmer wall struc-
tures to prevent recirculation of heated water at condenser water intakes.
Thermal stratification in the river upstream and downstream of the plant
site and the effect of condenser water outlet design are being studied.

MATERIALS AND MECHANICS
It was pointed out earlier that the traditional and familiar avenues for the
advancement of civil engineering through research include the develop-
ment of new materials and the study of the physical phenomena with
which the profession is concerned. In spite of the need for increased ef-
forts to improve the engineering process itself, the necessity for continued
basic research remains undiminished. It is trite but none the less true that
today’s basic research provides the solution of tomorrow’s engineering
problem. Countless examples of this can be given, but one in particular
deserves mention here. In about 1949, the Department conducted basic
research into the fluid mechanics of density-stratified flows. By the mid-
1950’s, this information was being used in the design of condenser
water intakes for conventional thermal power plants in the Tennessee
Valley. In the late 1950’s, concern with estuarial pollution produced a
need for the same technology applied to the stratification of fresh and
saline waters. More recently, these same ideas have led to the solution of
condenser water problems at large nuclear-thermal power plants and
have contributed directly to the Department’s international leadership in
the field of thermal pollution of water.

While most basic research contributes only to incremental advance-
ment of our engineering capability, there remain many technical areas
within civil engineering where a more thorough understanding of funda-
mentals would have a high probability of producing dramatic new meth-
ods and economies. We feel it is our responsibility to continue our leader-
ship role in basic research in civil engineering. At the same time, however,
the social and economic pressures of the times demand that we maximize
the return on our investment in such research by focusing our efforts on
those areas having the greatest probability of yielding significant results.
The following paragraphs serve to illustrate some of these areas and the
nature of our associated current research.

1. Sites having suitable foundation soils to support major structures are
being depleted rapidly and the civil engineer is having to construct large
structures on very weak and compressible soils. In the past, this would
have been considered economically, and in some cases technically, un-
feasible. This has emphasized the need to develop improved techniques
of evaluating stability and predicting deformations for these situations.

Research is under way concerning the application of analytical and
numerical methods to the study of the progressive failure of slopes in
overconsolidated clay and clay-shale. Procedures are being developed to
describe and to predict the formation of failure surfaces in such softening
soils. Slope-stability computer programs from this study are being
coupled with similar programs governing flow through porous media.

The use of finite-element methods for the solution of two-dimensional
consolidation problems is being studied with eventual extension into the
area of non-elastic stress-strain models.
Large-scale footing model tests are being performed on soft clays. The tests involve measurements of the amount and rate of settlement and total and pore water pressures in situ.

Experimental studies are being conducted on the influence of sample disturbance and stress system on the stress-deformation properties of clays, the bearing capacity of clays, and the effects of environment on the strength of clays. X-ray diffraction is being used to measure the clay fabric in a study of mineral-mineral friction. The strength and durability of stabilized soils are being studied.

2. Earthquake damage and failure of civil engineering structures constructed in seismically active regions is a continuously occurring problem. This points out the importance of developing methods of predicting the stresses and strains that are imposed on structures during an earthquake and the need for methods of designing structures to resist earthquakes. The Department is conducting research into the simulation of earthquake ground motion, the effect of local soil conditions upon these motions (and vice versa) and the interaction between soils and structures during earthquakes.

3. The development of analytical tools for handling the case of heavy loads on soft foundation soil and structures subjected to earthquakes has revealed the need to develop experimental techniques for measuring the material parameters needed for these new analyses. Such experimental work is under way in the various departmental laboratories.

4. The reflection, transmission, modulation and dissipation of water waves by natural boundaries and by man-made structures are fundamental processes of great importance to the design of breakwaters, sea walls, marinas, offshore and underwater structures, canals, and in the control of coastal erosion.

Experimental and theoretical research is being conducted into the surface profile and internal kinematics of a shoaling oscillatory wave up to and beyond the breaker.

Reflection and transmission of waves by bottom obstacles such as bars and berms are being studied theoretically and in the laboratory.

An explicit finite difference scheme has been used to develop a computer program for determining the tidal motions in estuaries and canals. This is being used to study the Delaware and Savannah estuaries, Chincoteague Bay, and the Cape Cod and Panama sea level canals.

5. The prevention of soil erosion by flowing water and the removal of deposited sediments for purposes of navigation or water quality control impose a heavy economic burden on society. We treat the symptoms of
this problem rather than effect a cure because of a lack of understanding of the underlying turbulent transfer mechanism.

We are experimentally measuring the effect which suspensions of spherical and non-spherical particles have on the structure of turbulence in a shear flow produced in a circular conduit.

A similar study, in which the shear field is independently variable over a wide range, is being conducted in the annulus between two concentric cylinders which rotate about a vertical axis.

Field studies in the Maracaibo Channel, Venezuela, are seeking the sources and motion of sediments and the distribution of salinity in order to reduce shoaling of the navigable channel and to reduce salt water intrusion into Lake Maracaibo. Companion laboratory studies are examining the flow variables and soil properties which control rates of erosion and deposition of fine cohesive sediment in a flow field.

Further experimental studies of the role of turbulence in sediment transport are being carried out by observing the structure of turbulence near rough porous boundaries.

6. Less than two years ago, two of our undergraduate students discovered that a high power continuous duty gas laser would drastically weaken hard, strong rocks in a few seconds. This could be important in machine-driving tunnels for transportation systems. Since the discovery, a great deal of further research work has been done in our laboratory and now the next step is being taken. This will involve a feasibility study on the problem of incorporating such a laser into the design of mechanical moles or tunnel boring machines which are presently unable to cut hard rock economically. (The laser will continuously weaken and will soften the rock to a point at which the mole can cut it easily.) If the study results prove to be positive, it is reasonable to expect that an experimental prototype will be developed for actual field trials. This latter eventuality might be two years distant.

Another technique for rock softening studied in the same program involves the use of surface active agents, chemical surfactants, to accomplish the same purpose, that is to say, make strong rock easier to cut and break. A number of these have been found and in the coming months a series of field trials on actual tunnel constructions now under way with moles will be performed. Still a third technique, using neither heat nor chemical action, has been discovered recently, but thorough research on it is just getting established so any evaluation now would be premature.

7. Several years ago we began to study the problem of microcracking in fibrous-glass-reinforced plastic composite materials. Caused by cyclic mechanical loading, this cracking fatigues the material and requires very
large safety factors on structural components in aircraft, missiles, pipelines, chemical tanks, and buildings. First, we found several ways to measure its severity and directionality directly. Then, we identified its causes, on a microstructural scale. Next, we made a series of experiments which showed that, in theory at least, it could be prevented. Finally, with the benefit of some good luck, we found a way to prevent it, by increasing the resistance of the plastic matrix to crack propagation by ten to 100 times, with little increase in cost and with no loss of other properties. (The same basic idea seems to work with cold, brittle asphalt also, which raises some interesting possibilities in the area of bituminous concrete.) Patents have been applied for, a number of large industrial companies are pursuing and developing the idea, and numerous field trials on engineering composites have been successful. In practice, the idea is sound.

8. A considerable fraction of our research effort in materials deals with their mechanics, in particular, how to represent properties analytically, for explicit design purposes. One of the most interesting classes, in this respect, is comprised of the viscoelastic materials, whose strength and stiffness are time-dependent. Asphalt is a good example. After a number of years of hard and patient work, we now have a method whereby multilayered structures composed of viscoelastic materials — pavements — can be analyzed fully for stresses and strains, under both single and cyclic loads, slowly or rapidly applied. The method has been computerized and in this form is being used for experimental purposes. We are optimistic about its wider adoption eventually, and the contribution it can make to more efficient and economical highway design.

UNDERGRADUATE ACADEMIC PROGRAM

During the past year, a new curriculum leading to the degree of Bachelor of Science without designation was made available to undergraduates. To qualify for a degree under this program, a student must complete the Institute requirements, must take five specific subjects in engineering science and must complete a program — jointly agreed upon between the student and his faculty advisor — of at least eight subjects aimed at a well-defined educational goal. Thus far, nine students have been accepted into this curriculum following submission of proposed programs of study.

The regular undergraduate degree program has an average enrollment of about 25 students per class. Once again, however, this figure fails to reveal the extent of the Department's involvement in undergraduate education at the Institute. For example, 1.00, Information Systems, was taken by more than 400 undergraduates this year and 1.10, Civil Engi-
neering Laboratory, had an enrollment of more than 40 students from outside the Department.

1.09, Civil Engineering, was again organized into two competing consulting engineering "firms." Their study of an airport facility on the Brewster Islands in Boston Harbor included an extensive analysis of travel demands, the effect of the new airport on urban growth, and computer simulation of aircraft operations. The results were presented formally by the students to a group of local political, business, engineering and civic leaders and have stimulated considerable interest in the potential of the Harbor.

GRADUATE ACADEMIC PROGRAM

The most significant development in the graduate educational program of the Department has been the rapid growth of the number of doctoral candidates. During the past five years, the total number of regular graduate students, controlled by quota restrictions, has increased modestly from 160 to 190 students. In the same period, the number of doctoral candidates has doubled, from 40 to 80. The trend in graduate degrees awarded is shown in the following table:

<table>
<thead>
<tr>
<th>Graduate Degrees Awarded</th>
<th>Three-year average (June, 1965-June, 1967)</th>
<th>June, 1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master's</td>
<td>68</td>
<td>71</td>
</tr>
<tr>
<td>Civil Engineer</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Doctoral</td>
<td>12</td>
<td>18</td>
</tr>
</tbody>
</table>

The current level of 18 doctoral degrees per year is exceeded only by three or four of the large state universities. The demand for civil engineering graduates at the doctoral level continues to exceed the supply. It is significant that an increasing number are being employed by more progressive consulting engineering firms.

In order to deal more effectively with the larger number of doctoral candidates, the faculty has revised the policies and procedures relating to the doctoral program in the Department. Under the new policy, the areas for doctoral study are designated by core programs formulated by faculty members of divisions or by interdivisional faculty groups. The core program that constitutes one-half of the student's total program of advanced study defines the area of his responsibility on the written and oral portions of the general examination. Students are required to take these examinations before the end of their fourth term of residence. In many
cases, this is as much as a year earlier than under the previous procedure. In addition to the earlier time element, the new policy permits a greater flexibility in the development of a total program of advanced study for each student.

Core programs for doctoral study have been developed in the areas of materials, transportation, structures, soil mechanics, hydrodynamics and water resources, civil engineering systems, urban systems engineering, and ocean engineering.

The rapid developments at the doctoral level in civil engineering have in no way diminished the concern of the Department with graduate education terminating at the Master's or Engineer degree.

The faculty are continuing to seek ways of encouraging students to include one or more years of engineering practice within the span of a graduate educational program. We have continued our efforts to bring our graduate students into contact with real engineering situations through the classroom as well. During the past year, 1.147, Engineering Systems Analysis, was concerned with water distribution systems for the City of New York; 1.152, Engineering Computer System Design, dealt with an urban information system for land use data; 1.148, Decision Theories in Engineering and Planning, studied planning for the Northeast Corridor between Boston and Washington; and 1.153, Engineering Computer System Management and Use, treated the selection of a computer system by the California State Highway Department.

The graduate subject offerings in the area of civil engineering systems were reviewed in detail throughout the year with the result that the sequences in numerical methods, linear algebra and optimization were substantially revised.

A new doctoral program in building systems has been developed and will be offered for the first time next year. This will provide a program of study based on systems methodology as applied to the planning, design and construction of buildings.

PERSONNEL AND ACTIVITIES
Professor John T. Christian gave a two-week summer program on the Application of Finite Elements to Soil Mechanics.


Professors Ronald C. Hirschfeld and Charles C. Ladd were lecturers at the Pan-American Soils Course held at the Universidad Catolica Andres Bellow immediately prior to the Caracas conference.

Professor Lambe became Chairman of the newly formed Committee
on Session Programs of the Soil Mechanics and Foundation Division, American Society of Civil Engineers (A.S.C.E.). The Soils Division will be hosts for an A.S.C.E. Specialty Conference to be held at M.I.T. in August, 1968. Professor Lambe is the general chairman of the Organizing Committee for this conference.

At the request of the Venezuelan Presidential Commission for the earthquake, Professor Whitman was a consultant concerning the 1967 Caracas earthquake, helping the Presidential Commission in ascertaining the effect of local soil conditions upon the great devastation during that earthquake, eventually leading to revised building codes and zoning procedures.

Professor Anwar E. Z. Wissa developed a data acquisition and processing system that is being used for experimental research in the soils laboratories.

Professor Hirschfeld was an invited speaker at the Rock Mechanics Symposium held in conjunction with the dedication of the new civil engineering building at the University of Illinois.

Professor Ladd was on leave of absence for the academic year and was a visiting consultant with the firm of Haley and Aldrich, Inc., of Cambridge, Massachusetts. He was elected to the nominating committee of the Boston Society of Civil Engineers and was active at conferences in Venezuela, Norway and Thailand.

Professor Lambe lectured at Harvard, the University of Illinois, the University of California, at Berkeley and at Los Angeles, the University of West Virginia and North Carolina State University.

Professor Leslie G. Bromwell was elected to the Committee on Physical-Chemical Phenomena in Soils and Professor Wissa was elected to the Committee on Soil-Portland Cement Stabilization, of the Highway Research Board.

Professor Whitman and faculty of the Structures Division are developing a strong departmental effort in earthquake engineering. As a group, they have worked on several nuclear power plant projects, especially as regards settling response spectra for design and analyzing other effects of local soil conditions.

Dr. Joseph M. Sussman joined the faculty as Assistant Professor of Civil Engineering. Professor Sussman is concerned with the areas of simulation, information systems and transportation systems.

Dr. Felipe Ochoa-Rosso joined the faculty for the year as Visiting Assistant Professor. Professor Ochoa's interest is in optimization and transportation systems.

Professors C. Allin Cornell, Marvin L. Manheim, Chiang C. Mei,
Peter J. Pahl, and Jay R. Walton were promoted to the rank of Associate Professor.

We are pleased to announce that Professors Ronald C. Hirschfeld and Charles C. Ladd were granted permanent tenure.

With regret, we report that Professors R. Brady Williamson and Ronald T. McLaughlin have resigned their positions on the faculty. Professor Williamson will take up a new position in the civil engineering department at the University of California at Berkeley, where he will develop a materials effort similar to ours. Professor McLaughlin will devote full time to his own consulting engineering firm, ENWATS.

Edward E. Newman, who has played a major role in assisting the profession in the use of research capabilities developed at the Civil Engineering Systems Laboratory, has been promoted to Senior Lecturer.

Professor Charles L. Miller has been appointed a director of the newly formed Urban Systems Laboratory (U.S.L.), which is an Institute-wide interdepartmental laboratory for research in the area of urban systems.

Professor Richard L. deNeufville has been appointed associate director of U.S.L. for the School of Engineering and Professor Walton has been appointed associate director of U.S.L. for computer systems.

Professor Daniel Roos has been appointed Director of the Civil Engineering Systems Laboratory (CESL).

CESL staff presented ICES seminars in Santiago, Chile, the University of Houston, the University of Oklahoma, and the University of Detroit.

Professors Roos and Frank E. Perkins addressed the First National Computer Congress in Bogota, Colombia.

Professor Pahl has returned from a year at the Technical University of Berlin, Professor Jose M. Roesset has returned from two years at the University of Chile, Professor Kenneth F. Reinschmidt from two years in the army, Professor Lambe from a sabbatical year of worldwide lecture and consulting tours, and Professor Eagleson from a sabbatical year of hydrologic research in Australia.

Professor Perkins was an organizer of the Boston Society of Civil Engineers lecture series on Computer Analysis, Design and Control in Civil Engineering.

Professor Eagleson gave lectures at the University of California at Davis, the University of Texas, the University of Iowa, Georgia Institute of Technology and the University of Minnesota.

Professor Marvin L. Manheim was active in organizing technical sessions for a transportation conference sponsored by the New York Academy of Sciences and the American Society of Mechanical Engineers. He was co-organizer of the International Design Methods Group Con-
ference and with Professor deNeufville again, participated in an Industrial Liaison Office symposium on transportation, in Los Angeles.

Professors Frederick J. McGarry, Russel C. Jones, R. Brady Williamson and Fred Moavenzadeh presented a two-week workshop on Civil Engineering Materials. Thirty civil engineering faculty members from schools in the U.S., Canada and Latin America spent two weeks at M.I.T. while we used our own research activities as a vehicle to demonstrate teaching methods, curriculum content, and general philosophy.

CHARLES L. MILLER

DEPARTMENT OF ELECTRICAL ENGINEERING
GENERAL STATISTICAL DATA
During the 1967-68 academic year the enrollment in the Department of Electrical Engineering was as follows:

<table>
<thead>
<tr>
<th></th>
<th>VI-1</th>
<th>VI-2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomores</td>
<td>160</td>
<td>58</td>
<td>218</td>
</tr>
<tr>
<td>Juniors</td>
<td>150</td>
<td>73</td>
<td>223</td>
</tr>
<tr>
<td>Seniors</td>
<td>163</td>
<td>62</td>
<td>225</td>
</tr>
<tr>
<td>Graduate students</td>
<td>430</td>
<td></td>
<td>430</td>
</tr>
</tbody>
</table>

The total number of undergraduates participating in the Co-operative Program (VI-A) was 86.

Degrees awarded in September, 1967, and February and June, 1968, were:

- Bachelor of Science: 112
- Master of Science: 147
- Electrical Engineer: 58
- Doctor of Philosophy and Doctor of Science: 38

The departmental staff was made up as follows:

- Assistant Professors: 39
- Associate Professors: 34
- Professors: 47
- Professors Emeriti and Senior Lecturers: 6
- Research Associates: 11
- Instructors (graduate students): 16
- Teaching Assistants: 104
- Research Assistants: 122
- Lecturers: 22

The distribution, by schools, of student enrollment in electrical engineering subjects during the academic year is indicated in Table I. The
relatively large component of students from other departments is evident, and is indicative of the “service” teaching load carried by the Department.

Table I Enrollment Statistics for the 1967-68 Academic Year

<table>
<thead>
<tr>
<th></th>
<th>Core curriculum</th>
<th>Computer</th>
<th>Laboratory</th>
<th>Elective</th>
<th>All undergraduate subjects</th>
<th>Graduate subjects</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Architecture</td>
<td>1</td>
<td>30</td>
<td>1</td>
<td>3</td>
<td>35</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>and City Planning</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
<td>66%</td>
<td>90%</td>
<td>71%</td>
</tr>
<tr>
<td>School of Engineering</td>
<td>1297</td>
<td>707</td>
<td>709</td>
<td>785</td>
<td>3498</td>
<td>1444</td>
<td>4942</td>
</tr>
<tr>
<td>School of Humanities</td>
<td>15</td>
<td>57</td>
<td>14</td>
<td>22</td>
<td>108</td>
<td>9</td>
<td>117</td>
</tr>
<tr>
<td>and Social Science</td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
<td></td>
<td>2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfred P. Sloan School</td>
<td>25</td>
<td>54</td>
<td>13</td>
<td>18</td>
<td>110</td>
<td>8</td>
<td>118</td>
</tr>
<tr>
<td>of Management</td>
<td>13%</td>
<td>6%</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Science</td>
<td>166</td>
<td>356</td>
<td>51</td>
<td>134</td>
<td>707</td>
<td>105</td>
<td>812</td>
</tr>
<tr>
<td>Undesignated Students</td>
<td>129</td>
<td>686</td>
<td>35</td>
<td>11</td>
<td>861</td>
<td>29</td>
<td>890</td>
</tr>
<tr>
<td>Total</td>
<td>1633</td>
<td>1890</td>
<td>823</td>
<td>973</td>
<td>5319</td>
<td>1596</td>
<td>6915</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>1247</td>
<td>510</td>
<td>694</td>
<td>579</td>
<td>3030</td>
<td>1308</td>
<td>4338</td>
</tr>
<tr>
<td>Non-Electrical Engineering</td>
<td>386</td>
<td>1380</td>
<td>129</td>
<td>394</td>
<td>2289</td>
<td>288</td>
<td>2577</td>
</tr>
</tbody>
</table>

UNDERGRADUATE PROGRAMS

During the last year, considerable effort was devoted to the development of new subjects and project laboratories. The general coordination of this work was maintained by the Undergraduate Educational Policy Committee (UEPC) under chairmanship of Professor Hermann A. Haus.

Further progress has been made on the development of the computer science curriculum. About 22 students have signified their intention of taking all, or most, of the sequence 6.231, 6.232, 6.233, 6.261 and 6.262J. They have been given permission to drop up to three of the normal Core Curriculum subjects in order to make place for these new subjects. (In addition, they must use some of their elective time.) Programming Linguistics, 6.231 (Professors John M. Wozencraft and Arthur Evans Jr.), was taught to undergraduates during both terms of the past year. The special computer language PAL (Pedagogical Algorithmic Language) has been implemented on the 7094 CTSS (Compatible
Time-Sharing Systems) system, and is being used as a basic part of the subject.

Computational Structures, 6.232 (Professor Jack B. Dennis), was taught to undergraduate students in both terms.

Information Systems, 6.233 (Professors Jerome H. Saltzer and Robert M. Graham), was taught to undergraduates for the first time in the spring term. Extensive notes have been written for all three subjects.

The additional fundamental mathematical background needed for computer sciences is provided by the following subjects:

Algebraic Foundations for Computer Science, 6.261 (Professors Frederick C. Hennie and Chung L. Liu), was taught for the first time in the spring. However, the subject matter is largely derived from a previous subject, Discrete Systems Analysis, 6.255, and is thus fairly well organized.

Computability, Formal Systems and Logic, 6.262J, 18.165J (Professor Hennie and Professor Manuel Blum of the Department of Mathematics), will be taught for the first time in the spring of 1969.

Work culminated this year on a revision begun in 1962 by Professors Herbert H. Woodson and James R. Melcher of Fields, Forces and Motion, 6.06, with the publication of the text, Electromechanical Dynamics, bound in three parts: Part I: Discrete Systems; Part II: Fields, Forces and Motion; and Part III: Elastic and Fluid Media. As a part of these activities, three 30-minute films, Synchronous Machines: Electromechanical Dynamics, by Professor Woodson, Complex Waves I: Propagation, Evanescent and Instability and Complex Waves II: Instability, Convection and Amplification, were produced by the Education Development Center for the National Committee on Electrical Engineering Films.

PROJECT LABORATORIES

The popularity of the project laboratories with both faculty and students is evident. Two new project laboratories have been added to the list announced in last year’s report; these are Advanced Digital Systems Project Laboratory, 6.721 (Professor Donald E. Troxel), and Modern Optics Project Laboratory, 6.722 (Professor Estil V. Hoversten).

VIDEO RECORDING

Professor William F. Schreiber has designed and installed a half-inch video tape system to be used as a “lecture facility” for Electronic Components and Measurement, 6.70, and Electronic Circuits and Signals Laboratory, 6.71. There are now 12 separate tape recordings of lectures.
on specialized laboratory problems (meters, operational amplifiers, etc.). These have been prepared by the faculty in a "do-it-yourself" studio. In the studio are three fixed cameras; one is aimed at the speaker, one at a writing pad, and one at the apparatus. The speaker has complete control of the apparatus at his lecture desk and he records his lecture without the aid of a technician. The student signs up to see the appropriate lecture when, and as, he feels it necessary for his work.

UNDERGRADUATE LABORATORY EQUIPMENT
The Department of Electrical Engineering has more than 700 students a year in its various undergraduate laboratories. About half their time is spent in more formal preparatory laboratory subjects and half in project laboratories. The problem of maintaining equipment levels against normal wear and tear, and of avoiding extreme obsolescence is very difficult. In addition, as new fields have grown in importance, we have had to add entirely new equipment to introduce the students to these technologies.

With grants from the National Science Foundation, and matching funds provided from the Ford Foundation grant to the School of Engineering, we spent $264,800 in 1966-67 and $217,869 in 1967-68 to re-equip and modernize our basic electronics and measurement laboratories, 6.70 and 6.71; to equip the new Digital Systems Laboratory, 6.711 and 6.721, with logic units, frames, and power supplies (designed and built in our shops); and to equip the Integrated Circuit and Solid State Project Laboratory.

In addition, the Department spent $4,700 to begin equipping the Modern Optics Project Laboratory, 6.722.

GRADUATE PROGRAMS
The enrollment in full-time graduate study of electrical engineering has been held constant for the past two years, and admissions were made in the spring of 1968 to continue at the same level during the 1968-69 academic year.

Horace M. Smith has taken over as secretary of the Committee on Graduate Students and secretary of the Committee on Admissions and Fellowships for the Department on the retirement of Colonel Frederic H. Fairchild.

Fellowship support for graduate students in the Department comes from a variety of sources, as outlined in Table II. An additional 58 of the Department's graduate students are supported through a total of 30 government and industry training programs.
Table II  Source of Fellowships Held by Graduate Students in the Department of Electrical Engineering

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of fellowships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic Energy Commission</td>
<td>2</td>
</tr>
<tr>
<td>Douglas Aircraft*</td>
<td>1</td>
</tr>
<tr>
<td>Grass Electronics*</td>
<td>4</td>
</tr>
<tr>
<td>Hertz Foundation</td>
<td>6</td>
</tr>
<tr>
<td>Hughes Aircraft</td>
<td>1</td>
</tr>
<tr>
<td>Industrial electronics (Research Laboratory of Electronics)*</td>
<td>4</td>
</tr>
<tr>
<td>M.I.T. endowed fellowships*</td>
<td>4</td>
</tr>
<tr>
<td>National Aeronautics and Space Administration (NASA) Traineeships*</td>
<td>5</td>
</tr>
<tr>
<td>National Defense Education Act (NDEA)*</td>
<td>7</td>
</tr>
<tr>
<td>National Institutes of Health (NIH) Traineeships*</td>
<td>10</td>
</tr>
<tr>
<td>National Science Foundation (NSF) Traineeships*</td>
<td>27</td>
</tr>
<tr>
<td>NSF Regular</td>
<td>50</td>
</tr>
<tr>
<td>Schlumberger Foundation*</td>
<td>1</td>
</tr>
</tbody>
</table>

*Awarded by the Department. All others awarded by the donor or agency.

NIH TRAINING GRANTS

During the past decade or so the involvement of faculty and students from the Department of Electrical Engineering in what we have come to call "communication bio-engineering" has grown almost explosively. The field of communication bio-engineering encompasses in a loose way the application of modern communication, control, and computer theory and technology to problems arising in the life and biomedical sciences. The extent of the departmental involvement can be measured by the fact that at least 24 faculty members (including visitors) and some 50 graduate students are currently committed to this field. The research program is concentrated largely in three groups in the Research Laboratory of Electronics (R.L.E.): cognitive information processing, communications biophysics, and speech communication. The current activities of these groups emphasize physiological and psychophysical studies of sensory systems, and man-machine studies of the generation and perception of communication symbols, including speech, handwriting, pictures, and tactile patterns.

To augment its sources of support for these activities (which come largely from the Federal government), R.L.E. this year applied for and received a training project grant from the NIH General Medical Services. This training grant, which has been approved for a period of at least five years, has two principal aims:

1. To support at any one time 12 to 15 predoctoral and four postdoctoral students. Support includes full tuition, a stipend ranging from $200 per month for first-year graduate students to $675 per month for an experienced postdoctoral scientist, plus dependency allowances and various
other benefits. The selection of these students is entirely under the control of M.I.T.

2. To encourage the development of a more comprehensive educational program in bio-engineering for these trainees as well as other students. The program will include the evolution of new academic subjects, laboratories and seminars. In particular, we seek to strengthen, as soon as possible, our offerings in the areas of system physiology and human biology; we hope that other institutions, such as the Harvard Medical School, will be able to assist us in this effort.

The first group of ten trainees began their studies in the 1967-68 year.

RESEARCH ACTIVITIES

The research activities of the faculty and graduate students of the Department of Electrical Engineering is largely but not entirely carried on within the administrative frameworks of the following laboratories:

Center for Materials Science and Engineering
Center for Space Research
Electronic Systems Laboratory
Project MAC
Research Laboratory of Electronics
Systems Engineering and Operations Research

All of these laboratories are interdepartmental, except for the Electronic Systems Laboratory, which is purely an activity of the Department of Electrical Engineering. In addition to these large laboratory groupings, there are smaller research activities. Summaries of the research in the large laboratories as well as in the smaller groups are presented in the following pages.

ELECTRONIC SYSTEMS LABORATORY (E.S.L.)

Faculty, staff members, students, and guests associated with the Laboratory conducted a diversified program of research in the areas of control systems and dynamic systems, computer applications, computer technology and information transfer and display, and aerospace systems and technology. Seventeen projects were active during the year, and are briefly reported below.

Total student participation was 110; 75 at the graduate level and 35 at the undergraduate level. Of these eight were Teaching Assistants, 33 were Research Assistants assigned to the Laboratory and 24 others were part-time employees. A total of 50 theses were completed, and degrees earned were as follows: nine at the doctoral level, five Electrical Engi-
neer, 25 Master's and 11 Bachelor's degrees. Electrical engineering faculty participation totaled 12, and 12 guest staff members from industry spent all or part of the year in the Laboratory.

Research in computer-oriented information-transfer systems for Project INTREX, led by Professor J. Francis Reintjes, Director of the Laboratory, and Professors Alfred K. Susskind, and James K. Roberge, was greatly expanded and is now one of the largest programs in the Laboratory. The initial goal of developing an experimental storage and retrieval system for 10,000 documents in the selected area of materials science and engineering should be reached by early 1969. The computer-base catalog and retrieval programs are about 90 per cent complete. Under the direction of Dr. Donald R. Haring, good progress is being made in the construction of a special computer display console designed especially for use with the enriched catalog stored in computer memory. An automatic microfiche retrieval device has been obtained which will permit rapid access to the full text of the 10,000 documents, and the high-speed facsimile system being designed for transmitting selected text pages to a remote terminal for soft-copy viewing and/or hard-copy print-out is in experimental test. The system will be evaluated experimentally in the M.I.T. Engineering Library.

The spacecraft radar group under Professor Reintjes continued work on a special radar instrument for measurement of the surface reflection of planetary bodies from fly-by or orbital vehicles. The initial system was flight-tested in a CV-990 aircraft flying over desert, mountain, farm, and water areas in the western U.S. in October, 1967. Data obtained provided useful information on the accuracy of the method, and indicated certain equipment deficiencies which are being corrected. In another radar research program under Laurence R. Swain Jr., and Godfrey T. Coate, work continued in the exploratory development of system and circuit techniques for implementing fine-resolution, synthetic-aperture, airborne ground-mapping radars. A novel, real-time, radar signal-correlation technique was demonstrated; and research was conducted on a wideband signal recorder and display using thermoplastic film. Some problems related to the use of fine-resolution radars to improve navigation accuracy in high-performance aircraft were studied.

The display group under John E. Ward, Deputy Director of the Laboratory, continued work in display systems for man-computer interaction. The PDP-7 buffer computer added to the E.S.L. Display Console at Project MAC was successfully placed in routine operation, and work is proceeding toward installation of a second E.S.L. Console with PDP-9 buffer computer in E.S.L. (Building 35) to be coupled to Project MAC via
a high-speed telephone data link. The prototype of the ARDS, low-cost, storage-tube display was completed, and this unit is now commercially available from a new company formed by former staff members Robert H. Stotz and Thomas B. Cheek. Seven of these displays, which have both alphanumeric and graphic capability and operate over a telephone line like a teletypewriter, will be installed in various M.I.T. departments this fall, and the display group is assisting in their system integration. Research was also conducted in new display circuits and techniques.

Professor Michael L. Dertouzos and the students working with him completed the first phase of CIRCAL-II, a second-generation program for on-line circuit design which provides much greater power and flexibility for use and growth than its predecessors, CIRCAL-I and AEDNET. Research continued on mathematical foundations for efficient on-line design, with emphasis on solution of non-linear networks by functional inversion and techniques for "tearing" networks for solution "a piece at a time." Also under development is an on-line "block diagram" system, LOTUS-I, for simulation of analog and digital systems. Dr. J. A. Narud, of the Motorola Corporation, was a visitor with the group during most of the year studying application of the techniques to integrated-circuit design.

The Computer-Aided Design Project, under Douglas T. Ross, Clarence G. Feldmann, and Jorge E. Rodriguez, continued research on AED (Automated Engineering Design) family of languages and systems, aided by nine visiting staff members from industry. The major accomplishment during the year was the "bootstrapping" of the AED-1 system from the IBM 7094 computer (Project MAC), on which it was developed, to the third-generation IBM 360-series and Univac 1108 computers, widely available in universities, industry, and government. System releases are scheduled by the respective computer manufacturers. Research continued on application of AED techniques to selected areas of mechanical design, and in further language and system development.

The interest of faculty and students in control-related activities continued at a high level, and there was considerable coupling with the academic program. The student control laboratory, which is operated as part of E.S.L., was completely refurbished in the process of being moved from Building 32 to Building 35 and provides much better facilities for laboratory instruction and student projects. Control-related research is as follows:

In cooperation with the Department of Chemical Engineering, Professor Leonard A. Gould and his students continued their research into problems of chemical process control and distributed systems. Particular areas of investigation are the stability of reactors, optimal and modal
control of discrete and continuous systems, and estimation of the state of continuous systems. Ivan Tenev, of the University of Sofia, Bulgaria, was a visitor with the group, and studied the estimation problem.

Professor George C. Newton Jr., Associate Director of the Laboratory, and the staff and students associated with him continued study of problems in the guidance and control of underwater vehicles, and in the application of real-time hybrid simulation and display technology to the problems of automotive driving task research and safe vehicle design. The PDP-1-X computer and its display, coupled with the T-200 analog computer and E.S.L.-constructed interface equipment, have been used for simulations to date, but the analog equipment will be transferred shortly to a new Adage AGT-30 Graphics System. This system, which is scheduled for delivery to E.S.L. in July, 1968, includes a digital computer and will provide much greater visual simulation capability. For the driving simulation, a driver's station is being constructed from a dismembered car. Mark E. Connelly of the group has assisted the NASA Electronics Research Center in planning and acquisition of a real-time simulation facility based on a PDP-10 time-shared computer.

Professors Michael Athans, Roger W. Brockett, Fred C. Schweppe, and Ian B. Rhodes and a team of graduate students continued their research in the fields of non-linear systems, stability theory, and deterministic and stochastic optimal control theory. The application of these techniques to several practical problems is being studied. These problems include control of aerospace vehicles, high-speed ground transportation, signal design for communication systems, and power generation and distribution systems.

A number of other research projects are in progress but can only be mentioned here. Professor Roberge and his students continued study of low-power circuitry for aerospace applications; W. Stewart Nicol, in cooperation with Professor David H. Navon, continued research in thin-film active devices using gallium arsenide FET structures; and Professor Reintjes and the staff and students associated with him are studying the application of computers in newspaper page layout, classified advertising, and news processing for retrieval purposes, in a project for the American Newspaper Publishers Association.

Both faculty and staff were active in presenting the results of their research at various meetings of the professional societies, and participated in the direction of society activities. John E. Ward completed his term as past President of the American Automatic Control Council (A.A.C.C.); Professor Athans was program chairman for the 1968 Joint Automatic Control Conference, was appointed Associate Editor of Automatica, and
served on the A.A.C.C. Theory and Education Committees; and Profes-
sors Schwepppe and Brockett chaired committees of the Institute of Elec-
trical and Electronics Engineers (I.E.E.E.) Group on Automatic Control.

The final phase of the move of the Laboratory to Building 35 from
Building 32 (its home since 1941) and various other locations in Build-
ings 10, 20, and 24 was completed during the year. The new quarters
offer an ideal environment for research activities.

Details of individual research programs were reported in 42 technical
reports issued by the Laboratory during the year, and are summarized
in the Annual Report of the Laboratory.

STROBOSCOPIC LIGHT LABORATORY
The interests in the Stroboscopic Light Laboratory continue to be directed
mainly towards pulsed light from gas-filled lamps discharged from energy
stored in electrical capacitors.

Dr. Tsuneyoshi Uyemura was a Visiting Professor (from the Univer-
sity of Tokyo) until January, 1968. He accomplished a research project
on the study of transient displacement of a string under tension. The re-
results of this study will be presented at the VIII International Congress on
High-Speed Photography in Stockholm, Sweden, on June 26, 1968, with
Professor Harold E. Edgerton as co-author. Many high speed photo-
graphic studies were made in the Laboratory by Dr. Uyemura of hydraulic
effects in the formation of drops of water and other liquids. A small selec-
tion was incorporated into an educational film for the Ealing Corporation,
Cambridge, Massachusetts.

An underwater elapsed-time motion picture camera was completed
and given many tests in the water of Boston Harbor. Professor Kenneth
Read of Boston University became interested in the use of the elapsed-
time camera for photographing sand dollars and starfish in action at one
to two frames per minute. The films are very revealing since all of the
creatures of the sea can be made to appear to move 500 to 1,000 times
faster than normal. During the summer of 1968, Professor Read and
Professor Richard Chesher of Harvard University will have an active
program with the elapsed-time camera filming sand dollars, sea urchins,
starfish, lobsters, flounders, snails, crabs and other sea life. A clock and
photocell light meter have been put near the subjects so that the camera
can see them for reference.

A project laboratory, Electronic Light Measurements Project Labora-
tory, 6.714, undertook the study of a special strobe lamp for photo-
graphing bird wings in action. It has been determined that an exposure
time of 70 to 100 microseconds is required to stop the wing action of
hummingbirds. Special flash lamps were made which produced a 65-microsecond flash from a special 30-watt-second electrolytic capacitor. Mark Khanna served effectively as the teaching assistant during the 1967-68 academic year.

POWER AND ENERGY RESEARCH

During the past year, a new research group concerned with problems of power generation and transmission has been formed within the Department. The newly funded Philip Sporn Professorship of Energy Processing has been awarded to Professor Herbert H. Woodson. Also in the group are Professors Schweppe, Gerald L. Wilson, and Gerald I. Stillman. Problems now under study include:

1. A study of the physical processes that lead to contamination flashover of outdoor insulation
2. A study of abnormal voltages in Extra High Voltage (EHV) transmission systems that result because of the periodic saturation of iron cores and transformers and the resultant ferroresonances
3. A study of the use of computers in the central control of interconnected power systems to improve reliability
4. A study of the feasibility of making more accurate analog scale models of power system components by the use of superconducting inductors and rotating machinery
5. A study of the use of superconducting field windings in large synchronous machines such as turbogenerators and synchronous condensers. If the technological problems can be solved, this technique promises to improve the electrical characteristics of such machines and to afford significant operating economies.

During the spring term, under the title of Engineering Problems, 6.241, Professors Stillman, Wilson and Woodson taught an elective subject on power system engineering. On the basis of experience gained in teaching this elective, a two-term sequence, Power System Engineering I and II, 6.551-2, was proposed and accepted by the Department for the first offering during the academic year 1968-69.

During the year, the research activities of the group have involved two doctoral candidates, five Master of Science candidates, and seven Bachelor of Science thesis students as well as four undergraduates doing laboratory projects for academic credit. Two Master of Science theses and seven Bachelor of Science theses were completed during the year.

As part of the continuing interaction with the power industry, Professor Schweppe spent half of the academic year working with the American Electric Power Service Corporation on problems of central control, and
Professor Stillman spent the academic year at M.I.T. on leave from the American Power Services Corporation.

HIGH VOLTAGE RESEARCH LABORATORY

Plans of the High Voltage Research Laboratory to improve its 3-MeV Van de Graaff electrostatic accelerator have been advanced by a grant from the Fannie E. Rippel Foundation. This accelerator is the principal apparatus used in the study of the physical properties of energetic electrons and their use in the treatment of superficial malignant disease in humans. The modified generator will produce electron beams with energies up to 5 MeV.

A portion of this grant will be applied to the purchase of a 3-million-volt X-ray source of a new design, to advance the physio-clinical studies of radiation therapy of deep tumors. This program, in which an average of 50 patients are treated daily in the High Voltage Research Laboratory, is conducted in cooperation with physicians of the Lahey Clinic Foundation of Boston, especially of Dr. Magnus I. Smedal and Dr. Ferdinand A. Salzman. The new accelerator, expected early in 1969, is of the compressed-gas-insulated Van de Graaff type and will possess clinical features aimed at the more precise localization of the radiation energy in the tumor-invaded region and the protection of surrounding normal tissue. The 3-MeV X-rays are more energetic and penetrating than the gamma rays from cobalt 60. The expected beam intensity corresponds to a radioactive material source of more than 15,000 curies.

The Laboratory has continued its investigations of vacuum insulation of high voltage systems emphasizing processes which contribute to the initiation of instability. Reports of this work were presented by Professor John C. Trump in the opening paper at the Symposium on High Voltage Insulation in Vacuum in London. A Master’s thesis on the effect of thin dielectric films was completed by Philip C. Bolin in June. A doctoral thesis by Chathan M. Cooke on semivacuum insulation is in progress.

The Laboratory’s long experience in the use of compressed gases to insulate high voltage systems has been applied during the past several years to an investigation directed at the realization of compressed-gas-insulated lines for the underground electric power transmission. This work, which received a grant from the Edison Electric Institute in October, was summarized at the winter power meeting of the I.E.E.E. and in a doctoral thesis by Herbert J. Doepken Jr.

Under the guidance of Kenneth A. Wright and Dr. Salzman the Laboratory has led in the direct injection of megavolt electrons for the control of extensive tumor areas located just below the skin. The growing ap-
preciation of the advantages of this form of therapy has led to an increased 
flow of patients with widespread skin involvement and to the initiation 
of corresponding electron therapy at several other treatment centers. 
During the year the Laboratory staff began the study of the feasibility of 
developing a very compact and flexible megavolt electron accelerator for 
this therapeutic purpose.

In addition to Institute support, the work of the High Voltage Research 
Laboratory was made possible by grants for specific research from the 
Damon Runyon Memorial Fund, the National Institutes of Health, and 
the Lahey Clinic Foundation.

LABORATORY FOR INSULATION RESEARCH

The research on electrical polarization and conduction in pure water and 
ice and the effects of doping agents advanced as planned and new insight 
about the origin of relaxation spectra emerged. On the basis of these 
fundamental studies, cooperation with Naval medical research is develop-
ing, especially on blood plasma preservation questions. This fits into our 
long-range program to use dielectric spectroscopy as a diagnostic tool for 
living systems.

The work on high-temperature dielectrics for the Air Force continues, 
with special emphasis on the millimeter wavelength range. William B. 
Westphal is in charge of the dielectric measurements effort. Professor 
Arthur R. von Hippel guides the research program of the Laboratory and 
acts as a consultant to the Office of Naval Research. During May he gave 
invited lectures at London University and in Eindhoven, Stockholm, 
and Copenhagen.

SYSTEMS ENGINEERING AND OPERATIONS RESEARCH

Professor Alvin W. Drake and several graduate students have studied 
operational aspects of certain public systems. Some of the students and 
their areas of interest are: John B. Jennings, regional blood-banking sys-
tems; Richard C. Larson, urban police operations; Keith A. Stevenson, 
emergency ambulance services; and Joseph Ferreira, consistent strategies 
for automobile insurance systems. Reports on the first three of these 
projects have been published by the M.I.T. Operations Research Center.

During the past year, Robert J. Gladstone completed his doctoral 
thesis on the scheduling and congestion aspects of a proposed high-speed 
ground transit system. Martin Eisenberg presented his thesis on multi-
queue single server systems for which there are probabilistic descriptions 
of the server's changeover times. James S. Kakalik is presently attempting 
to optimize service policies for such complex queuing systems by utilizing
the techniques of Markovian decision theory. Professors Philip M. Morse of the Department of Physics, John D. C. Little of the Sloan School of Management, Robert G. Gallager, and Drake have participated in the supervision of these research activities.

PARTICLE OPTICS LABORATORY

The Particle Optics Laboratory, under the direction of Professor Charles K. Crawford, is engaged in several projects. A program to explore the feasibility of using small-diameter electron beams as current or voltage sources to test microcircuits is continuing. These beams would be focused onto contact pads built into a microcircuit; and, in theory, the pads could be as small as one micron in diameter while still maintaining a current capability of about $10^{-6}$ ampere. Current is limited by the brightness of the electron source. Calculations showed that either electron mirror microscopy or secondary electron energy distribution measurements might be used to determine the surface potential of each pad being bombarded. Thus it should be possible to obtain signal outputs directly from the interior of a circuit under test, as well as to inject voltage signals by use of feedback. An additional feature of this technique is that it is compatible with new fabrication methods based on charged-particle-induced chemical reactions. Combining these two technologies in the same vacuum system should make very large arrays of ultra-small components practical, by allowing in situ discretionary wiring to proceed concurrently with testing.

Another continuing project concerns the design of ion sources suitable for the ion implantation of semiconductors, and sources suitable for the study of ion-induced reactions. Sources are being built which are compact and require only low power. Work is being devoted to the incorporation of mass analysis, the attainment of maximum possible brightness, and the reduction of ion energy spreads to a minimum. Contract support has been obtained for the study of ion-induced reactions in photoresists and a few other materials. Ion-induced reactions have an advantage over electron reactions, in that the ion range is shorter, and thus the resolution should be higher. Unfortunately, they have the disadvantages of fundamentally lower reaction rates (due to lower source brightness as well as more stringent perveance limitations) and greater experimental complexity.

Cross sections for the single and multiple ionization of metal vapors by electron impact are being collected (and published) using a large quadrupole mass spectrometer. Several improvements in the data-collecting electronics, the electron and atomic beam feedback stabilization, and
the vacuum system were made during the past year. A new type of thermal manipulator suitable for use in high vacuum was designed and a report was published. One model is currently in use as a beam shutter; many other applications seem potentially useful.

CONTINUUM ELECTROMECHANICS
The primary and continuing goal of this group, supervised by Professor Melcher, is to create a coherent scientific and engineering body of knowledge concerned with electrohydrodynamics — the electromechanical interaction between electric fields and fluids. Projects which range from basic studies to the exploration of techniques for achieving engineering objectives are usually aimed at developing a close tie between an analytical model and an experiment. A significant basic advance concerned with electrical relaxation effects on the dynamics of liquid interfaces has made possible the engineering design of zero-gravity, dielectrophoretic liquid orientation devices using dc fields.

Quantitative predictions have been correlated with experimentally observed instabilities and steady cellular convection flows connected with electrical shear stresses. This work has led to the development of a new class of flows wherein a slightly conducting fluid is both contained and pumped by a “conduit” that has electrical, but not mechanical, walls. The instability and convection of slightly conducting liquids under combined electrical and thermal stress has been quantitatively predicted in simple configurations, with application to the control of convective heat transfer in slightly conducting liquids.

“Resistive wall” traveling-wave interactions of both an electrohydrodynamic and magnetohydrodynamic nature have been developed theoretically and take advantage of energy storages in electric structures to produce generators having the virtues of a self-excited induction generator not requiring capacitors. During the past year, Professor Charles D. Hendricks, Visiting Professor from the University of Illinois, has participated in the research activity, carrying out investigations of charged liquid particles connected with the development of colloid propulsion for small space vehicles.

CENTER FOR SPACE RESEARCH
The involvement of the Department in the activities of the Center for Space Research is continuing, especially in the area of space communications.

Department faculty participation includes Professors John V. Harrington, Wilbur B. Davenport Jr., Robert S. Kennedy, and Robert D. Yates.
In addition, two lecturers from the Department are responsible for the solar radar and solar plasma probe programs in the Center.

Graduate student interest in the Center is continuing; this year five research assistants have been appointed in the Center's Laboratory for Space Experiments, and a graduate student has held an NIH fellowship. In other research areas within the Center, two Lincoln Laboratory Staff Associates are working on their doctoral programs. At the post-degree level, Visiting Engineers from Japan and France have participated in the work of the Center.

The main areas of activity have been the study of space communications, analysis of phased-array antennas, and electronic design associated with the Sunblazer experiment. Presently under way are two Master of Science theses, two Bachelor of Science theses, and a Doctor of Science thesis, the latter dealing with the problem of communications through a dispersive medium. The phased-array antenna efforts include analysis of the combined effects of random phase errors and quantization effects. A second doctoral thesis involves the construction and flight of a gyro-stabilized balloon gondola to examine the spatial structure of cosmic X-ray sources.

CENTER FOR MATERIALS SCIENCE AND ENGINEERING

In these paragraphs highlights of the work of the electrical engineering faculty and students in the Center for Materials Science and Engineering are presented. In addition, there have been several students working at the Lincoln Laboratory with Professor Alan L. McWhorter on problems of phonon-plasma interactions in solids. During the past year, 18 faculty and 83 graduate students from electrical engineering were doing research in the Center.

The materials theory group, directed by Professor George W. Pratt Jr., is working on the basic physical and electronic properties of solids. Starting with the determination of the energy band structure, the group is using this information to find impurity levels in the Pb salts PbTe, PbSe, and PbS. Specifically, the wave functions and energies for Pb vacancies and negative component vacancies are being investigated. The band structure is further used to find the wave vector and frequency dependent dielectric constant $\epsilon(k,\omega)$. This electromagnetic response function describes many of the electronic properties of a solid as well as being closely related to the phonon spectrum. Experimental work is continuing on frequency modulation of semiconductor lasers by ultrasonic waves. The group first demonstrated this effect at 2 Mc and is now extending the modulation frequency to 1,000 Mc. Further experimental work is under
way with PbSe investigating the lasing properties when a valley-splitting strain is imposed. This technique may provide a tunable far infrared source and the possibility of a phonon laser. The group is also active in the area of magnetism. In particular, an investigation of the nature of ferromagnetic coupling in narrow bands has been carried out. This has resulted in a precise picture of the role played by electron correlation effects. The theoretical techniques used in the narrow band problem can be generalized to discuss the melting and liquid-gas phase transitions. A very successful theory for the boiling points of the alkali metals has been worked out.

The Crystal Physics Laboratory under the direction of Professor Alexander Smakula is engaged in fundamental research on crystal growth and the physical properties of crystals. The laboratory also provides crystals to other groups at the Institute and elsewhere on a cooperative basis. Facilities are available for growing crystals by various techniques, including aqueous solution, high-temperature solution, Czochralski, Bridgman, flame-fusion, and hydrothermal synthesis. The laboratory has research equipment for ultraviolet and infrared spectrophotometry and fluorescence spectroscopy, high-precision lattice constant determination, high-precision density determination and dielectric measurements. Present research is concerned mainly with preparation and study of pure and doped simple and mixed oxide and fluoride crystals. The optical absorption is studied at room temperature and low temperatures from vacuum ultraviolet to 50 microns in the infrared. The emission, excitation and lifetime of luminescent crystals are also under extensive study. Low-temperature transitions in ferroelectric crystals is another topic under investigation. New laser crystals for the blue and infrared spectral regions are also under development. The dielectric study of semiconductors at low temperature is another research field.

The principal objective of the microwave and quantum magnetics group continues to be the clarification and exploitation of those properties of ferri- and antiferromagnetic insulators which have significance for electronics applications. Professor David J. Epstein and his students have been concerned with studies of magnetic loss mechanisms with a view toward their control in applications where low loss is an important criterion for design, and their utilization where a material must be intentionally absorptive. Professor Frederic R. Morgenthaler and his students have been primarily concerned with microwave magnon/phonon/photon interactions. Interest in this new field of what may be called “microwave magneto-ultrasonics” is warranted because of the fundamental information concerning spin-elastic wave interactions which can be obtained
from magnetic and/or ultrasonic spectroscopy and because these interactions make possible novel microwave devices such as magnetoelastic wave parametric amplifiers, tunable delay lines and pulse compression filters. Work during the past year has included studies of the frequency and temperature dependence of the anisotropic resonance losses in silicon doped yttrium-iron-garnet (YIG); the propagation of magnetoelastic waves in YIG in spatially uniform and time-varying magnetic fields and the frequency and mode conversion of such waves; phonon-pumped magnon instabilities in gallium substituted YIG; non-linear processes which couple uniform and spin wave magnons in the antiferromagnet RbMnF₃; and the interaction between nuclear and electron resonance modes in this same material. In addition, we have initiated studies of conductivity and Hall effect in YIG, the influence of photon excitation on the low-temperature resonance losses in YIG, phonon pumping in RbMnF₃, and coupling effects occurring among phonons, magnons and photons at interfaces between magnetic dielectrics.

The general theme of the work undertaken in the semiconductor materials and devices group is the relationship between electronic device capabilities and limitations, and the materials employed. These capabilities and limitations may stem from the material itself, or from technology associated with device fabrication. Our work, which covers both aspects, is carried out by Professors Richard B. Adler, Paul E. Gray, Robert H. Rediker, David H. Navon, Arthur C. Smith, Richard D. Thornton and Bruce D. Wedlock, Floyd O. Arntz, John N. Churchill, John S. Moore, Daniel L. Smythe Jr., James N. Walpole and Stephen D. Senturia. In addition, one Instructor, Walter H. Berninger, and one Research Associate, Julio H. Serebrinsky (Visiting) are associated with this group. Twenty-nine graduate students are participating in the program, and the degrees granted during the year have included three Bachelor’s, 13 Master’s, and four doctorates. External support has come from the Advanced Research Projects Agency (ARPA), NASA, ONR (Office of Naval Research), AFOSR (Air Force Office of Scientific Research), U. S. Army Electronics Command, U. S. Department of Commerce, NSF Fellowships and Ford Fellowships.

The group has devoted its activities in the past year to the interaction between successive diffusants in silicon integrated-circuit technology, including the role of stress and dislocation development in these phenomena; electrical effects of stress concentration at “window” edges in passivating layers on silicon; the analysis of the anomalous X-ray transmission which occurs in X-ray topography; the electro-optical (Franz-Keldysh) effects in SrTiO₃ and GaAs, as well as very high-frequency
forms of these and related non-linear optical effects; the effect of pumping and bleaching radiations on optical absorption in CdS; the thermal instability and secondary breakdown in transistors; the analysis of high-injection phenomena in semiconductors; the development of high-power transistors for use in new kinds of high-power high-frequency motors with large power-to-weight ratios, and design of associated circuitry for brushless commutation and rapid charging of batteries for electric vehicle propulsion systems; the Knight-shift of Pb$^{207}$ and Te$^{125}$ nuclear resonances in PbTe, as a function of conductivity type, carrier concentration and temperature (in cooperation with the materials theory group); and the use of computers in circuit design, with a view eventually toward the special problems of integrated circuits.

In addition, in a program to study the physical parameters related to the performance of devices in PbSe, low carrier concentration material has been produced by two-zone annealing. The depth of diffused p-n junctions has been calculated for the theoretically predicted different diffusion constants in p and n type material and compared with experimental results for a variety of initial conditions. The lifetime of minority carriers is being studied as a function of material parameters and temperature by investigating the rise and fall times of the luminescence from PbSe optically pumped by a GaAs laser. High field conduction phenomena are also being investigated. To understand the properties of luminescence and laser action in semiconductors further, the luminescence from direct- and indirect-gap semiconductors is being studied as a function of electric field and phonon population. The temperature dependence of the threshold for laser action in optically pumped InAs has been explained in terms of lesser degree of mode confinement in the optically pumped lasers than in diode lasers. In the program on heterojunctions, effort is now being concentrated on the electrical and electro-optical characteristics of InSb-InAs heterojunctions.

**RESEARCH LABORATORY OF ELECTRONICS**

In the Research Laboratory of Electronics (R.L.E.), faculty and students from a dozen academic departments conduct basic research in three broad fields: general physics, plasma dynamics, and communication sciences and engineering.

The research in general physics includes a variety of topics such as molecular beams, microwave spectroscopy, radio astronomy, solid-state microwave electronics, optical and infrared spectroscopy, noise in electron devices, electrodynamics of media, and physical optics of invertebrate eyes.
SCHOOL OF ENGINEERING

The research on plasma dynamics includes studies of the basic properties of plasmas as well as engineering applications such as controlled nuclear fusion for energy conversion. Intensely ionized plasmas are being produced both by high-power electron beams and by microwave radiation. Plasma phenomena in solids are being studied theoretically and experimentally.

The research on communication sciences and engineering includes studies related to signal generation, transmission, processing, and utilization in man-made and living systems. The major areas of research are circuit and system design, communication theory, information processing and transmission, linguistics, speech communication, cognitive information processing, communications biophysics, and neurophysiology.

A combined research and training program in communications bioengineering was initiated two years ago. This program is based on the research in speech communication, cognitive information processing, communications biophysics, and neurophysiology. The program provides increased opportunity for doctoral training of electrical engineering students in areas related to the life sciences, as well as postdoctoral training for biological or medical scientists.

The Department of Electrical Engineering is the largest participant in the research activities of R.L.E. Currently, about 56 of the Department's faculty, five postdoctoral research staff, 175 graduate students and 57 undergraduates are engaged in a variety of projects spanning most of the research categories mentioned above.

During the last year, 24 doctoral, 15 Engineer's, 43 Master of Science and 32 Bachelor's theses in electrical engineering were based on research supported by the Laboratory.

The following paragraphs summarize some of the R.L.E. research activities in which electrical engineering faculty members and students have participated during the past year.

As part of the research in radio astronomy, Professor David H. Staelin has been engaged in the measurement of atmospheric line profiles of water vapor and ozone, and is currently building a multichannel radiometer to pursue the study of weak atmospheric lines. Professor Staelin also worked with Professor Bernard F. Burke of the Department of Physics in making a measurement at 9.24 mm wavelength of the cosmic background radiation which is presumably the remnant radiation of the primeval fireball.

The solid-state microwave electronics group, under the direction of Professor Robert P. Rafuse, is continuing its activities in the area of high dynamic range instrumentation with a preliminary high-frequency
mixer design having third-order distortion products 120 decibels below a milliwatt two-tone input. A completely solid-state receiver at 60 Gigahertz is under construction with a noise figure design goal of 4 to 6 decibels. Theoretical and experimental studies are under way on mixers, frequency multipliers, IMPATT and "anomalous-avalanche" diode oscillators and general technology associated with high dynamic range, low noise instrumentation for transmitters, receivers, and signal processing systems.

The electronic instrumentation group, supervised by Dr. Donald H. Steinbrecher and Professor Jerome I. Glaser, has concentrated on improving the resolution of a precision mass spectrometer. A double-focusing high-resolution spectrometer was housed in a wrought-iron electromagnetic shield and mounted on an air support system to isolate it from building vibrations. Computer simulation of the particle flight path permitted studies of power supply interference effects on resolution. New low-noise power supplies are now being built to increase both the resolution and the long-term stability of the system. Various detection schemes are also being studied in order to provide the instrument with real-time readout and a direct interconnection with a digital computer.

Professor Haus and his students have measured the impulse response of a CO2 laser amplifier (at 10.6 microns) and have obtained agreement with theoretical principles. The input pulses, produced by a gallium-arsenide electro-optic modulator, had rise and fall times shorter than a nanosecond. The amplified pulses had rise and fall times of the order of ten to 30 nanoseconds.

Dr. Gary D. Bernard, in collaboration with Dr. William H. Miller of the Yale University School of Medicine, has discovered three new contrast filtering structures in insect compound eyes. These are reflection interference filters in the butterfly, diffraction filters in the skipper, and transmission interference filters in some flies. In a doctoral thesis by John L. Allen, a new waveguide mode theory for optical functioning of the so-called "superposition" compound eye has been evolved. The group has recently succeeded in making direct observations in support of this theory.

The active plasma systems group, under the supervision of Professors Louis D. Smullin, Abraham Bers, Richard J. Briggs and Ronald R. Parker, has continued its experimental studies of the beam-plasma discharge, and theoretical studies of linear and non-linear wave interactions in plasmas.

The work of Professor Smullin and graduate students Rulon K. Linford and Joseph A. Mangano has been concerned with a detailed study
of the energy distribution of the ions and electrons in the plasma of a beam-plasma discharge. A retarding field analyzer was built to measure the energy of the particles escaping along the magnetic axis of the system. The analysis of the data reveals not only the energy distribution but the plasma potential as well. The results of these experiments were checked by comparison with the measurement of the Doppler broadening of the He 4685.75Å ion line. These measurements were made possible by a pulse sampling and integrating technique that examined the monochromator output, during any predetermined part of the discharge, and automatically averaged over many separate discharge pulses.

The effect of multipole stabilization on a beam-plasma discharge has been studied in a smaller beam-plasma system by Professor Parker and Felipe N. Herba. It has been found that relatively modest currents in a hexapole winding stabilize a class of low-frequency instabilities which heretofore have plagued the beam-plasma discharge.

The non-linear dynamics of some plasma phenomena have been studied by computer simulation techniques by Professor Bers, Jon A. Davis and Herman M. Schneider. Such a study of the beam-plasma interaction has revealed the detailed development of the non-linear regime in which plasma electrons become heated. Another study concerning the oscillations of a bounded, inhomogeneous plasma has shown the detailed non-laminar dynamics which are responsible for the collisionless damping that is observed in such oscillations.

During the past year Professor Bers and Professor George Bekefi of the Department of Physics formed a new group to study plasma effects in solids. The interests of the group are in non-equilibrium effects that show promise for new electron device applications. Noise and coherent radiation from 30 MHz to 10 GHz have been observed in n-type InSb at 77° Kelvin, when parallel electric and magnetic fields (3-20 volts/cm, and 700-3,000 Gauss) are applied. Experiments are being conducted to determine the mechanism responsible for these emissions. Theoretical studies of electron-phonon interactions have shown microwave amplification of acoustic waves to be feasible in acoustically active materials with high mobility, such as InSb, in the presence of a dc magnetic field which reduces electron diffusion.

The communications biophysics group, under the direction of Professors Walter A. Rosenblith and William M. Siebert, continued its studies of the physiological and behavioral implications of neuroelectric and other activity observed in various sensory systems, particularly the auditory system.

Research in psychophysics supervised by Nathaniel I. Durlach has
focused on binaural hearing and perception of intensity relations. The research on binaural hearing has led to an increased understanding of our abilities to localize sound sources and to detect signals in backgrounds of interference, and of how these abilities are limited by imperfections in the peripheral transformation from acoustical waveforms to neural firing patterns in the auditory nerve. The research on the perception of intensity relations has provided further insight into how our capabilities to detect, discriminate, identify, and scale are related to each other and to fundamental limitations of sensitivity and memory.

Dr. Robert D. Hall has completed several studies of brain activity in the behaving animal, describing changes in acoustically evoked potentials in the auditory pathways of the rat as a function of sleep and waking, and as a function of several drug-induced state changes. Professor Stephen K. Burns and his students have developed a number of instruments and techniques that are useful for processing EEG and EKG records. A technique has been devised by Professor Richard W. Henry for recording from sensory and motor nerve cells in crayfish while the animal is relatively free to respond reflexively to various sensory inputs. Several important studies of the dynamic and fluctuating properties of nerve membrane have been completed by students of Professor Thomas F. Weiss. Professor Peter G. Katona (in association with Dr. G. Octo Barnett of the Massachusetts General Hospital) has succeeded in describing quantitatively certain components of the system which causes reflex changes in heart rate as a result of variations in blood pressure.

Several experimental projects were carried out by members of the group in the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary. Measurements of responses in the auditory nerve of cats have led Dr. Nelson Y. S. Kiang (with Dr. Julius L. Goldstein, from the Laboratory of Psychophysics, Harvard University) to conclude that certain subjective combination tones could result from non-linear processes in the inner ear. Professor Michael L. Wiederhold has determined the effect of stimulation of the efferent olivocochlear bundle on the responses of single auditory nerve fibers. Professors Weiss and William T. Peake (with Dr. Harvey Sohmer, on leave from Hadassah Medical School, Jerusalem) have measured electrical responses from within the inner ear to determine the relationship of these potentials to acoustic stimuli. Some aspects of the organization of cells in the superior olivary complex have been determined through coordinated physiological and anatomical work (in cooperation with Dr. R. Kent Morest, Department of Anatomy, Harvard Medical School).

During the past year Professor Jerome Y. Lettvin and his associates in
the neurophysiology group have accumulated evidence which indicates that the terminal tree of neuron acts as a shaped filter for the statistics of interpulse intervals in the axon itself. The notion, if generalized, transforms violently our present concepts of the operation of a nervous system.

In the cognitive information processing group, the acquisition of two new data-processing systems has greatly enhanced the power of our research facilities for biological image processing and for sensory aids research. The purpose of the work on biological image processing is to develop automatic, objective procedures useful in clinical pathology and biological research. Professor Murray Eden, Dr. Oleh J. Tretiak and Dr. James E. Green, and their students are experimenting with digital procedures for the high-speed data acquisition and analysis of biomedical images, including peripheral blood smears (for both leukocytes and erythrocytes), vaginal smears (for cervical cancer) and chromosome spreads.

In the area of sensory aids, Professors Samuel J. Mason, Francis F. Lee, Troxel and their students are developing an improved free-standing version of a reading-machine system, capable of scanning and recognizing printed text and producing artificial speech output. The system will be used in studies of the capabilities and requirements of blind subjects as users of such reading machines.

The speech communication group, under the supervision of Professor Kenneth N. Stevens, has continued to examine the nature of the speech production and perception processes, and to apply knowledge in these areas toward the development of machines for the synthesis and recognition of speech. During the past year, analyses of the acoustic properties of speech sounds and experimental data on speech-sound perception have led to more quantitative definitions of the quantal feature-generating capabilities of the vocal tract and the feature-detecting attributes of the speech perception mechanism. These findings are being complemented by studies of the process whereby children acquire the capability to perceive and generate the sound sequences of speech. These and other experimental studies have been enhanced recently by the acquisition of new computer facilities for the examination and display of speech data, for the manipulation of speech signals, and for the simulation of various aspects of the speech process.

The information processing and transmission group has been concerned with efficient and reliable communication techniques. Professors Kennedy and Hoversten and their students have been studying the efficient utilization and fundamental limitations of optical communication
channels. They have developed both coding theorems and near-optimum communication techniques for such channels with an emphasis on atmospheric turbulence, clouds, and quantum limitations. Professor Gallager and his students have made advances in the areas of sequential decoding, source coding subject to a fidelity criterion, and error correction on burst noise channels.

The detection and estimation theory group under the supervision of Professor Harry L. Van Trees continued work in the area of optimum signal processing. The major emphasis was on the utilization of state variable and Markov process techniques to solve processing problems in radar, sonar, and communication systems. In addition to the research effort, current results have been organized into a coherent theory for presentation to graduate students and practicing engineers. This latter effort was published as a two-volume set, *Detection, Estimation, and Modulation Theory: Part I* (1968), *Part II* (in press), by H. L. Van Trees.

**PROJECT MAC**

Project MAC, an interdepartmental research facility in the computer sciences, receives its largest faculty and student participation from the Department of Electrical Engineering. Project MAC is directed by Professor Robert M. Fano, and Professor Joseph C. R. Licklider has recently been appointed Associate Director. During the past academic year this research community included 17 members of the electrical engineering department faculty, one research associate, one instructor, three teaching assistants, seven lecturers, 31 research assistants, seven fellowship students and ten undergraduate students. In addition, 19 other members of the departmental faculty, two lecturers and approximately 20 research assistants, graduate and undergraduate students were associated with Project MAC for the purpose of exploring the use of its time-sharing computer system in other areas of electrical engineering.

Professor Fernando J. Corbató has been leading the development of the MULTICS (time-sharing) System. A major milestone in this research effort was reached in December, 1967, with the successful integrated check-out of a critical part of the system representing approximately one-half of the operating system software. By the end of June, 1968, most of the parts of the system necessary for initial operation have been integrated and checked out. However, analysis of the system's operation indicated that various parts had to be modified and, in some cases, re-designed to achieve a satisfactory level of performance. Major improvements of performance have already been achieved, and further significant
improvements are expected to result from modifications currently in progress. Professors Graham and Saltzer, in addition to collaborating with Professor Corbató in this research and development effort, have been distilling new knowledge and insights resulting from this work into a new undergraduate subject on information systems. In particular, this subject employs as a framework for student exercises a fully documented example of a time-sharing system which is, in effect, a simplified version of MULTICS.

Professor Marvin L. Minsky is leading a research project aimed at the development of a visually controlled manipulator. A major part of the effort has been devoted during the past year to understanding the vision problem, that is, the relations between spatial geometric situations and optical measurements. As this body of knowledge is developed, it must be represented in the computer programs for analyzing pictures into three-dimensional structures. Therefore, a second concern has been the development of problem-solving programs that can manage spatial geometric information. An important piece of theoretical work has been completed by Professor Minsky in collaboration with Professor Seymour A. Papert of the Department of Mathematics on the pattern recognition capabilities and limitations of Perceptrons. This work will be presented in an M.I.T. Press monograph which is currently in press.

Professor Dennis and his students have been concerned with the fundamental aspects of the representation of computation processes and information structures, and their application to the organization of general-purpose computer systems. During the past year much of the group’s effort was focused on parallelism, both in the description of computations and in the functional organization of computer hardware. Two recently completed doctoral theses have developed new insight into these areas, and a third one has provided a theoretical framework for resource allocation in multi-access computing systems. This research has strongly influenced the development of a new undergraduate subject on computation structures.

Professor John J. Donovan and his students have been interested in formal systems for the definition of programming languages. In particular, a program has been written which accepts as input the definitions of a source language and a target language, and then recognizes well-formed sentences in one language and translates them into the other one. Professor Zvi Kohavi has been studying various problems associated with the design of finite-state machines having fault detection capabilities, and with the general areas of reliability improvements and machine diagnosis.
Professors Wozencraft and Evans, in collaboration with Dr. Martin Richards, have been engaged in a research effort jointly sponsored by the Department of Electrical Engineering and Project MAC and intimately connected with the development of an undergraduate subject on computer linguistics. Work during the past year has included the design and implementation of a new programming language, BCPL, which was then used to implement another new language, PAL, intended specifically for educational use.

Professors Joseph Weizenbaum and Robert R. Fenichel have developed a program for computer-aided instruction in programming, again under the joint sponsorship of the Department of Electrical Engineering and Project MAC. This program has been successfully used by students in the spring term, and an improved version is currently being developed for use in the fall term, 1968.

A doctoral thesis entitled, "Symbolic Integration" was completed by Joel Moses, who has since been appointed Assistant Professor in the Department. A product of this thesis is a program that can perform symbolic integration at the level of a competent mathematician. It uses heuristic techniques similar to those used by people; for instance, it inspects the integrand to decide what approach, such as integration by parts or substitution of variables, is most likely to simplify the integral, and changes approach if the integral is not thereby simplified. A very interesting aspect of this program is that it stores significant knowledge about calculus in the same sense that a book does, but with the very important difference that such a knowledge can be used directly without being first absorbed and practiced by a person.

Professor Liu and his students have been engaged in research in a variety of subjects ranging from an algebraic structure theory of information processing machines to the design and implementation of compiler systems.

A more detailed report on Project MAC appears elsewhere in this volume.

STUDENT ACTIVITIES AND AWARDS

STUDENT-FACULTY COMMITTEE

In the interest of further improving core-subject teaching and for better feedback between students and teachers, the Committee developed a questionnaire which was circulated late in the first term. As a starter, it was restricted to one subject, Electromagnetic Fields and Energy, 6.03. The student response was high. The results were discussed in an open
committee meeting with the instructor in charge of 6.03. The results were also used to refine and improve the original questionnaire.

In the second term the improved questionnaire was circulated among all Course VI undergraduates covering a broader range of core subjects. Again, the response was high, and the information is in the process of being compiled for further discussion in the fall.

The Committee also ran its two popular Senior and Faculty Steak Banquets. About 225 students and faculty attended each banquet. The students had as their guest of honor at the May banquet retiring Institute Professor Harold E. Edgerton.

BETA-THETA CHAPTER OF ETA KAPPA NU

The Chapter continued to add to its listing of schools offering graduate study in electrical engineering. This list is probably the first of its kind in the country and was started by the Chapter in 1961 when no other such compilations could be found. The list, insofar as possible, gives the areas in which a department specializes. It also lists M.I.T. faculty who may be acquainted with the school, and — with the help of the Alumni and Placement Offices — lists the number of M.I.T. men going to each of the schools and the range of their cumulative ratings.

This list has resulted in a number of people applying for graduate schools who otherwise would not because they thought their grades were too low. A number of other Eta Kappa Nu Chapters throughout the country have requested copies of our lists to serve as models for their own use.

At its spring initiation, the Chapter inducted Professor James D. Bruce of M.I.T. as a Professional Member.

SCOTT PAPER FOUNDATION LEADERSHIP AWARD

This year the Department again captured the Scott Paper Award. The award consists of $1,500 towards senior-year tuition plus an additional $1,500 towards tuition in the first year of graduate study and is presented each year to an engineering student in his junior year in recognition of demonstrated high character, actions on behalf of the welfare of his colleagues, and potential for making outstanding contributions to the professional aspects of engineering in business and industry. The award was given to David L. Lyon, a third-year student in Program 2 who is doing cooperative work at Bell Telephone Laboratories under Course VI-A.

MORRIS J. LEVIN AWARDS

These awards given for excellent performance through independent work in undergraduate laboratory projects, were given to the following under-
graduate students: Michael A. Bromberg '70, for his project "Logicaleodon — A Music Generator and Recognizer" performed in Digital Systems Project Laboratory, 6.711; Richard S. Gawlik '69 and John M. Smutek '69 for their project, "Automatic Recognition of Handsent Morse Code with a Teletype Output," also performed in 6.711; William H. McCandless '69 for his project "Fabrication of a MOSFET Transistor" performed in Semiconductor Devices and Circuits Project Laboratory, 6.719; and David W. Kress Jr. '68 and Ronald E. Reder '69 for their joint project, "A Bottle Watcher — Monitoring the Supply of Intravenous Solution," performed in Bioelectronics Project Laboratory, 6.712.

NEREM STUDENT AWARD WINNER
The winner of the annual NEREM Student Awards Competition was Hoo-Min David Toong for his paper entitled "Interpretation of Atmospheric Emission Spectra near 1cm Wavelengths." Mr. Toong's faculty supervisor was Professor Staelin.

FACULTY
RETIREMENT
Professor Harold E. Edgerton, one of the best-known members of the Department’s faculty, came to the age of retirement this year. To the students, “Doc” is a friend, the guy playing the guitar at the Stu-Fac Steak Fry, the one who insisted that they build things with their own hands (be doers rather than sitters), and the one who taught them to find excitement in their work. To the faculty, many of whom were his students, he has served as a continued source of encouragement and inspiration. Professor Edgerton came to M.I.T. as a graduate student and research assistant in 1925. He received the M.S. degree in Electrical Engineering in 1927 and in 1928 he was appointed Instructor of Electrical Engineering. In 1931 he received the Sc.D. degree and in 1932 he was promoted to Assistant Professor. In 1938, he was appointed Associate Professor; in 1948, Professor; and in 1966, Institute Professor. We are fortunate that Professor Edgerton has decided to continue to teach next year as an Institute Professor Emeritus.

LEAVES OF ABSENCE
Professor Peter Elias was on sabbatical leave during both terms of the academic year. He spent this time at Harvard University's Division of Applied Sciences, teaching, writing, and doing research.
Professor Robert L. Kyhl was on sabbatical leave for both terms at the Physics Institute of the Eidgenossische Technische Hochschule in Zurich. Professor Paul E. Gray took his sabbatical leave during the spring term. He spent most of this time at the University of North Wales lecturing and writing. He also spent time traveling in Europe.

Professor Pratt took his sabbatical during the spring term, dividing his time between studying and writing in Vermont and at Dartmouth College.

During the fall term Professor Campbell L. Searle was on leave at M.I.T. writing a textbook jointly with Professor Paul E. Gray on solid-state devices and circuits.

Other leaves of absence included: Professor William B. Lenoir, who has been designated a Scientist-Astronaut by NASA and spent the year in training at the NASA Manned Spacecraft Center in Houston; Professor Peter R. Gray, who continued his work in signal processing at the General Atronics Corporation in Philadelphia; Professor Alan V. Oppenheim, who was at Lincoln Laboratory conducting research in digital signal processing techniques and homomorphic filtering; and Professor Joel E. Schindall, who spent the year at Watkins Johnson in Palo Alto designing high-speed digital circuits.

NEW MEMBERS OF THE FACULTY

Dr. Joseph C. R. Licklider joined the Department in December as Professor of Electrical Engineering. Dr. Licklider is no stranger to M.I.T. From 1950 to 1957 he was Associate Professor of Psychology and Communications in the Department of Electrical Engineering and during the 1965-66 academic year he was a Visiting Professor of Electrical Engineering. In his research activities, he is associated with Project MAC and the efforts there to advance the art and understanding of computer systems with which people can interact directly.

Robert M. Graham joined the faculty as an Associate Professor of Electrical Engineering after spending a period of time as a member of the D.S.R. Staff at Project MAC. Mr. Graham's interests are in the area of time-shared computer systems.

Dr. Ian B. Rhodes, whose major interest is modern control theory, was appointed an Assistant Professor of Electrical Engineering in February after completing his doctorate at Stanford University.

Dr. Robert D. Yates, who held a NASA Postdoctoral Fellowship at the Jet Propulsion Laboratory, was appointed Assistant Professor of Electrical Engineering in October. Dr. Yates' field of interest is communication theory and his research is based in the Center for Space Research.
Other new Assistant Professors include two former Research Associates — Dr. David Adler, whose interests center in the area of solid-state materials, and Dr. Arthur L. Anger, whose interests are in computer science.

Appointed Assistant Professors after receiving doctorates from M.I.T. were Dr. Stephen K. Burns, bioelectronics; Dr. Jerome I. Glaser, electromagnetic fields; Dr. Joel Moses, computer science; Dr. Ronald R. Parker, plasmas; Dr. Daniel L. Smythe, semiconductor materials and devices; and Dr. Michael L. Wiederhold, communication bioengineering.

RESIGNATIONS
Professor Alan H. Barrett transferred from the Department of Electrical Engineering to join the Department of Physics.

Assistant Professor Peter R. Gray resigned his post to work in industry.

Associate Professor Edward L. Glaser resigned to become Director of the Jennings Computation Center at Case Western Reserve University.

Associate Professor William B. Kehl resigned to become Director of the Computing Network at University of California at Los Angeles.

Assistant Professor Harry B. Lee resigned to join the M.I.T. Lincoln Laboratory.

Associate Professor Alfred K. Susskind resigned to become Head of the Electrical Engineering Department at Lehigh University.

VISITING FACULTY
During the past year the Department once again had a large number of visiting faculty.

Dr. Thomas J. Bridges, a member of the technical staff of the Bell Telephone Laboratory at Murray Hill and an authority on infrared and submillimeter lasers, spent the first term of the academic year assisting in the establishment of a laser facility and consulting with students and faculty on laser techniques and problems. He held an appointment as Visiting Professor of Electrical Engineering.

Dr. Mildred S. Dresselhaus, a staff member at the M.I.T. Lincoln Laboratory, spent the year in the Department as Abby Rockefeller Mauzé Visiting Professor. She joined the Department's solid state group, where she participated in the research program and also taught Project Seminar, 6.12, Electric Properties of Solids I, 6.647, and Electric Properties of Solids II, 6.648. She is widely known for her experimental and theoretical work in energy bands and phonon structure. The Abby Rockefeller Mauzé Professorship was established in 1963 by gifts from Laurance S. Rockefeller and the Rockefeller Brothers Fund to bring to
M.I.T. distinguished women scholars who would inspire the women students at M.I.T. as well as enrich their professional education.

Dr. Charles D. Hendricks, Professor of Electrical Engineering at the University of Illinois at Urbana, spent the year as Visiting Professor of Electrical Engineering. During his stay at M.I.T., Professor Hendricks taught recitation sections of Fields, Forces and Motion, 6.06, and conducted research in electrohydrodynamics at the Center for Space Research.

Professor Janak R. Handa, Professor in the Department of Electrical Engineering at the Birla Institute of Technology and Science in Pilani, Rajasthan, India, spent the year as Visiting Associate Professor of Electrical Engineering. Professor David C. White was Professor Handa's host at M.I.T.

Dr. Jean Germain Charles Hanus, a member of the Research Staff of the Solid-State Division of Lincoln Laboratory, was a Visiting Associate Professor during the second term when he taught Quantum Theory of Magnetism, 6.65, while Professor Pratt was on sabbatical leave.

Dr. Richard W. Henry, Associate Professor of Physics at Union College in Schenectady, New York, spent the year as a Visiting Associate Professor while he taught Principles of Transistors I, 6.341, and Circuits, Signals and Systems, 6.05, and performed research in the communications biophysics group of the Research Laboratory of Electronics to further his understanding of the nervous system. Dr. Henry will also be at M.I.T. during the 1968-69 academic year.

Chi C. Lee, Associate Professor at the Institute of Electronics, National Chiao Tung University, Taiwan, China, was a Visiting Associate Professor during the year. The purpose of Professor Lee's visit to M.I.T. was to give him an opportunity to observe and participate in the teaching activities of the Department of Electrical Engineering.

Dr. David H. Navon continued during the past year as a Visiting Associate Professor, teaching Semiconductor Devices and Circuits Project Laboratory, 6.719, participating in the activities of the Center for Advanced Engineering Study and conducting research in the Center for Materials Science and Engineering. Dr. Navon's research is centered around semiconductor devices and integrated circuits.

Dr. Kalluri Ramalingsarma, Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Technology in Kanpur, was a Visiting Assistant Professor during the second term, participating in the teaching activities of the undergraduate electrical engineering laboratory subjects and the research activities of the cognitive information processing group of the Research Laboratory of Electronics. Dr.
Ramalingsarma will continue his visit during the first term of the 1968-69 academic year.

Dr. Fred C. Schweppe continued his appointment as Visiting Associate Professor of Electrical Engineering during the year. Professor Schweppe's activities are centered in the Department's energy processing area, particularly in the problems of central, reliable control of power systems. During the first term Dr. Schweppe was on leave at the American Electric Power Service Corporation in order to study the problems of power system control first-hand; during the second term he taught Seminar in Control Research, 6.603. Professor Schweppe will join the Department's regular faculty at the beginning of the 1968-69 academic year.

Gerald L. Stillman, a member of the technical staff of the American Electric Power Service Corporation, was a Visiting Associate Professor of Electrical Engineering during the year. He taught Electromagnetic Fields and Energy, 6.03, and Circuits, Signals, and Systems, 6.05; participated with Professors Woodson and Wilson in teaching an undergraduate seminar in power systems engineering, and conducted research in the Department's Energy Processing Laboratory.

Dr. Tsuneyoshi Uyemura, an authority on mirrored cameras at the Institute of Industrial Science of the University of Tokyo, spent the first term as a Visiting Professor participating in the research activities of Professor Edgerton's Stroboscopic Light Laboratory.

Dr. Lotfi A. Zadeh, Head of the Department of Electrical Engineering and Computer Sciences at the University of California at Berkeley until January, 1968, spent the second term as Visiting Professor prior to returning to his teaching and research roles at Berkeley. During this visit Professor Zadeh was a Guggenheim Fellow and participated in the research activities of Project MAC.

FACULTY AND STAFF AWARDS

Professor Harold E. Edgerton received the Richardson Medal from the Optical Society of America for his distinguished contributions to applied optics and his outstanding contributions to the field of high-speed photography.

Professor Joseph C. R. Licklider in March, 1968, received the Alumni Award from Washington University for outstanding achievement and service which reflects honor upon the University.

Professor Paul E. Gray was appointed to the post of Assistant Provost, and was also named the Class of 1922 Professor, to succeed Professor
John Wulff. As Assistant Provost, he will be responsible for the coordination and development of the undergraduate curriculum.

Professor Gordon S. Brown, Dean of the School of Engineering, was awarded the Honorary Doctor of Engineering Degree by the Stevens Institute of Technology in Hoboken, New Jersey.

The Honors and Awards Committee of the American Society of Magazine Photographers awarded a Special Technical Award to Professor Alexander Smakula for his contribution to photography in perfecting the technique of antireflection coatings which enhanced images and made possible advanced designs in lenses.

Professor Michael L. Dertouzos was awarded the Browder J. Thompson Memorial Prize, presented for the best paper in any of the publications of the Institute of Electrical and Electronics Engineers by an author under 30 years of age. Professor Dertouzos’ paper was “PHASE-PLOT: An On-Line Graphical Display Technique.”

Professor Robert G. Gallager was named a Fellow of the Institute of Electrical and Electronics Engineers (I.E.E.E.) for his contributions to information theory and error correcting codes.

Professor Marvin L. Minsky was named a Fellow of the I.E.E.E. for his research and educational leadership in the field of artificial intelligence and heuristic programming. Professor Minsky was also elected a Fellow of the American Academy of Arts and Sciences.

Professor Jack P. Ruina was elected a Fellow of the American Academy of Arts and Sciences.

Professor Louis D. Smullin was named a Fellow of the American Physical Society.

John E. Ward, Associate Director of the Electronic Systems Laboratory and Lecturer in Electrical Engineering, was named a Fellow of the I.E.E.E. for his outstanding contributions to computer controlled systems.

Professor Abraham Bers received a Certificate of Award from the Gordon Research Conference for his activities as 1967 Chairman of their conference on Plasma Physics.

Professor James D. Bruce was inducted as an Alumni Member at the installation of the Texas Zeta Chapter (at Lamar State College of Technology, Beaumont, Texas) of Tau Beta Pi.

Charles L. Seitz III, an Instructor in the Department of Electrical Engineering, was presented the Goodwin Medal at the Institute’s 1968 graduation exercises. The Goodwin Medal is presented in memory of Dr. Harry M. Goodwin, the first Dean of the Graduate School, to graduate students for conspicuously effective teaching.

The Supervised Investors Services, Incorporated, Awards, presented
DEPARTMENT OF MECHANICAL ENGINEERING

to graduate students who are members of the teaching staff of the Department of Electrical Engineering for excellence in teaching, went this year to Arthur Alan Bushkin, John Gabriel Kassakian, and Ian Theodore Young. Messrs. Bushkin and Young are Instructors in the Department and Mr. Kassakian is a Teaching Assistant.

LOUIS D. SMULLIN

DEPARTMENT OF MECHANICAL ENGINEERING

The Department's new organizational structure of three major divisions was brought fully into play during the past year under the following inaugural chairmanships:

Mechanics and Materials Division: Professor Stanley Backer
Thermal and Fluid Sciences Division: Professor Warren M. Rohsenow
Systems and Design Division: Professor Herbert H. Richardson

These chairmanships are rotating, and Professor Stephen H. Crandall will assume the leadership of the Mechanics and Materials Division for the next three years. In its first year of operation the new structure appeared to be achieving its objectives very well. It has been especially helpful in reaching sound and equitable policy decisions on staffing.

At the meeting of the departmental Visiting Committee the program was mainly on the theme of the Department's expanding involvement with research fields motivated by societal needs, in contrast to problems arising in industry or, more commonly in the three decades since World War II, from military and aerospace requirements. This substantial trend was warmly commented upon by the Visiting Committee, whose members expressed particular pleasure with the purposiveness and sense of direction of these efforts. The Department's activities concerned with current problems of human welfare lie mainly in the fields of biomedical engineering and the urban scene. The scope of the undertakings appears in the text.

UNDERGRADUATE PROGRAM

REGISTRATION

Our total undergraduate enrollment has remained approximately constant, as shown by the figures following:

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<thead>
<tr>
<th></th>
<th>1966–67</th>
<th>1967–68</th>
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<tbody>
<tr>
<td>Sophomore</td>
<td>60</td>
<td>46</td>
</tr>
<tr>
<td>Junior</td>
<td>50</td>
<td>68</td>
</tr>
<tr>
<td>Senior</td>
<td>64</td>
<td>56</td>
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<td>174</td>
<td>170</td>
</tr>
</tbody>
</table>
A predominance of seniors graduating in June went on to graduate school, with the draft situation in 1968 reflected through an increase in number in those going into industry and the armed services:

<table>
<thead>
<tr>
<th></th>
<th>1967</th>
<th>1968</th>
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<tbody>
<tr>
<td>Graduate school, M.I.T.</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Graduate school, other</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Industry</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Foreign study</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Armed service</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Undecided or unknown</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>42</td>
</tr>
</tbody>
</table>

BACHELOR OF SCIENCE DEGREE, UNDESIGNATED
Professor Ernest Rabinowicz continues to serve as advisor to students working towards the Bachelor of Science degree without specification. Currently there are three seniors and nine juniors enrolled in the program. There are no sophomores this year, but indications are that about six students will enter the program in the fall at the start of their junior year. Nearly half the students are interested in the general area of controls, system analysis and computer applications, while the others wish to go on to careers in such widely far-flung areas as medicine and oceanography.

Our Department has been joined this year by the Department of Civil Engineering in offering an unspecified Bachelor of Science degree program.

UNDERGRADUATE SUBJECTS
Under the chairmanship of Professor Peter Griffith the Department Curriculum Committee continues its efforts to increase the coherence of the undergraduate program. The new thermodynamics sequence received particular attention and appears to have been well received by the students.

The text for Dynamics, 2.03, *Dynamics of Mechanical and Electromechanical Systems*, by Stephen H. Crandall, Dean C. Karnopp, Edward F. Kurtz and David C. Pridmore-Brown was published by McGraw-Hill Book Company just in time for the spring term. In Vibrations, 2.06, Professor Allan D. Pierce incorporated the IBM 1130 computer into the subject by assigning homework problems requiring computer solutions for undamped and lightly damped multimodal systems.

Professor Charles A. Berg designed a new subject, Solid Mechanics, 2.071, to replace Strength of Materials, 2.08. The new subject treats the
mechanics and physics of elastic, plastic and viscoelastic deformation with application to structural analysis, fracture and properties of composites and is designed for students in fields which make extensive use of solid mechanics such as metallurgy and materials science, geophysics, naval architecture, metals processings, and surface phenomena, as well as for students in mechanics who desire an introduction to advanced graduate subjects in solid mechanics.

The introductory sophomore science distribution subject, Introduction to System Dynamics, 2.02, was further developed this term by Professors Richardson and David N. Wormley. A major effort was devoted to the development of a laboratory portion of this subject. A small-scale general-purpose test apparatus and operational amplifier manifold was designed, fabricated and submitted to preliminary evaluation by Professor Wormley to provide a facility for the study of active circuit design, investigation of instrument compensation and signal processing systems and the analog simulation of dynamic systems.

Professor Ronald C. Rosenberg continued subject and text development for Computer Models of Physical and Engineering Systems, 2.101, which is taken by a wide spectrum of students from freshmen to seniors, many of them from other departments. This subject utilized for the first time the hands-on capability of the IBM 1130 digital computer located in the Department.

Professor Henry M. Paynter continued activities in developmental teaching of electromechanics at the undergraduate level through the regular subjects, Electromechanical Fields and Systems, 2.13J, and Dynamics, 2.03. As part of an evolving Institute curriculum effort in electromechanics and electric power systems, Professor Paynter is also planning a new interdisciplinary senior-graduate subject tentatively entitled Electromechanical Control Systems.

Professors Thomas B. Sheridan and William R. Ferrell, assisted by William L. Verplank, expanded Man-Machine Systems, 2.18T, to a 12-unit subject and continued development of text material.

Professor David G. Wilson offered the project laboratory subject, Design and Experiment, 2.67, for the second time in the spring term. Professor Igor Paul organized the junior subject, Engineering Design, 2.731, and Professors Richardson, Forbes T. Brown and Dwight M. B. Baumann supervised the design sections. An innovation was to choose the same project topic, "Pollution, Waste Disposal and Reclamation," for both the sophomore project laboratory and the junior design subject. The common theme resulted in student projects ranging from improved waste disposal methods for Boston to the design of a non-polluting steam
SCHOOL OF ENGINEERING

automobile. A series of lectures by visiting authorities in the theme area was given to students in both subjects. As a result of faculty exposure to the important problem of waste disposal, Professor Wilson organized a summer study on solid-waste disposal in which he and Professor Paul will be participating this summer along with faculty members from several departments.

In the senior subject, Design Concepts, 2.732, Professor Baumann and his students traveled to the Whirlpool Corporation for a briefing on the problems of futuristic laundry systems and household icemakers. Students undertook projects in these areas and made a presentation to company representatives at the end of the term in which several innovative solutions were discussed. Two students received a deFlorez Prize for their creative approach to a laundry system for apartment dwellers.

In Engineering Design and Manufacture, 2.861, Professor Deane Lent confronted the sophomore class with the problem of designing a simple machine for carrying on patterning exercises in brain-injured children. Several excellent and practical designs resulted, one of which received the first deFlorez Prize for creativity in mechanical engineering.

Professor Wilson offered a revised version of Applied Thermodynamics, 2.60, based on a case study approach designed to acquaint students with techniques used in applying thermodynamics to practical problems of current interest. The design of a basic oxygen furnace to reduce pollution was considered during the fall term, and the design of a deep-submergence submarine during the spring. Students were divided into groups of four or five, each of which took different approaches to the problems and prepared competitive proposals for their solutions. The final examination was replaced by an oral presentation of the various proposals to a panel of interested faculty and industrial representatives. In general these presentations were excellent and student reaction to the subject was favorable. It is anticipated that the approach will be continued.

A revised presentation of Thermodynamics, 2.403, was presented for the first time by Professors Joseph L. Smith Jr. and Ernest G. Cravalho with the objective of presenting thermodynamics in a manner closely related to the student's previous background and emphasizing the effective modeling of real situations for thermodynamic analysis. The presentation was well received because it made the utility of thermodynamics apparent to the students. Development of this subject is continuing.

Other changes in undergraduate thermodynamics include the elimination of Statistical Mechanics and Kinetic Theory, 2.404, due to lack of student interest and the withdrawal from participation in the joint offering
DEPARTMENT OF MECHANICAL ENGINEERING

Thermodynamics and Statistical Mechanics, 2.41J, due to its rather narrow focus on problems primarily of interest to aeronautical engineers. Professor Griffith was responsible for organizing the teaching of the projects laboratory subject, Experimental Engineering, 2.671T. Approximately one-third of the experiments were replaced by new ones.

During the past year the nine-unit Physical Measurement and Analysis, 2.651, aimed at upperclassmen, was phased out while the sophomore 12-unit subject, 2.654, with the same title, increased in popularity. The 41 students who took 2.654, taught by Professors Nathan H. Cook, Pangal N. Nayak, Rabinowicz and Walter D. Syniuta, are majoring in 13 different departments at the Institute.

The new science distribution undergraduate subject, Polymer Materials Science, 2.901J-10.641J, was introduced jointly by Professor Ioannis V. Yannas and by Professor Allan S. Hoffman of the Department of Chemical Engineering. It will be repeated with a number of modifications in the coming year.

UNDERGRADUATE SEMINARS
The Department again offered a wide variety of undergraduate seminars, as follows:

Fall Term
Douglas P. Adams — The Birth and Care of a City
Modern Marvelous Mechanical Motions
Augustus R. Rogowski — Engineering and Research in Piston Engines
William R. Ferrell — Human Decision Making in Vehicle Guidance

Spring Term
Douglas P. Adams — The Birth and Care of a City
Modern Marvelous Mechanical Motions
Augustus R. Rogowski — Engineering and Research in Piston Engines
Frank A. McClintock — Problem Solving and Creativity
Henry M. Paynter — The Size and Shape of the Universe
William R. Ferrell — Human Decision Making in Vehicle Guidance

ENGINEERING PROJECTS LABORATORY
The Engineering Projects Laboratory (EPL) continued to maintain an effective interdisciplinary grouping of staff, equipment, and services, so that undergraduates, graduates, and faculty could work together on a variety of problems. Participating in laboratory research activities were 31 professors, five instructors and 100 graduate students. In addition, Laboratory facilities were extensively utilized for undergraduate theses,
undergraduate laboratory subjects (2.67 and 2.671), and freshman seminars. Laboratory personnel presented weekly EPL Colloquia covering a wide variety of research topics.

A new laboratory facility, the Power Systems Engineering Laboratory, developed by Professor Herbert H. Woodson of the Department of Electrical Engineering, became associated with EPL. A number of large research projects were transferred into the main laboratory area in order to utilize that area more effectively. Instrument room facilities were improved by extensive purchases of new equipment, including calibration standards. Procedural changes were made to simplify internal information reports and to establish a more efficient system of document filing and retention. A revised version of the Policies and Procedures of EPL was issued.

During this past year, Professor Arthur E. Bergles served as Chairman of EPL, and Paul A. Wieselmann served as Coordinator.

GRADUATE PROGRAM

ENROLLMENT

In September 1967, 231 graduate students were enrolled in the Department of Mechanical Engineering as full-time students. In addition, 20 special students worked full-time and took only one subject in the Department. Of the regular students, 137 held Institute appointments as Instructors, Teaching Assistants, or Research Assistants. Seventy received fellowships or industrial support and five were U. S. military students.

Of the students who enrolled in September, about 22 per cent were citizens of foreign countries: 25 from Asia, seven from Canada and England, and the remainder from South America, Europe and the Near East.

About 60 of the enrolled students received their undergraduate degrees from M.I.T. Forty-three students had degrees from foreign universities. The remaining students had degrees from the following universities in the United States: General Motors Institute, Rensselaer Polytechnic Institute, City College of New York (six each); Cornell University and Union College (five each); University of Illinois, Iowa State University (four each); University of California at Berkeley, Northeastern University, Purdue University, Stanford University, Stevens Institute of Technology, Worcester Polytechnic Institute (three each); Clarkson College, Columbia University, University of Connecticut, Cooper Union, Lafayette College, Louisiana Polytechnic Institute, Lowell Technological Institute, University of Michigan, University of Minnesota, University of New
DEPARTMENT OF MECHANICAL ENGINEERING

Hampshire, North Carolina State University, Notre Dame University, Princeton University and the U. S. Naval Academy (two each); and other universities including Harvard University, Lehigh University, Swarthmore College, Case Institute of Technology, U. S. Coast Guard Academy and U. S. Merchant Marine Academy.

DEGREES AWARDED

In February, the Department awarded six Doctor of Philosophy and seven Doctor of Science degrees, four Mechanical Engineer degrees and 21 Master of Science degrees.

In February, 232 graduate students registered in mechanical engineering and of them, three received Ph.D. degrees, eight received Doctor of Science degrees, eight received the Mechanical Engineer degrees, and 26 received Master of Science degrees in June. Of the students remaining in the Graduate School, 69 have passed the Qualifying Examination and are working, or will start, on their doctoral programs.

In September, approximately 24 students should receive their Master of Science degrees in mechanical engineering. Since the Department does not allow doctoral thesis presentations in the summer term, doctoral students completing their degree work in the summer will officially graduate in February, 1969.

FORECAST FOR SEPTEMBER, 1968

Estimates of actual enrollment in September of 1968 are extremely difficult to make in light of the unsettling developments with regard to Selective Service and the graduate student, as well as to the unpredictable possibilities of reductions in government funds available for research.

SUBJECTS

A major restructuring of the advanced subjects in solid mechanics is under way by Professor Berg and his associates. The first step was the introduction of Solid Mechanics, 2.071, as a senior elective or first-year graduate subject. This will be followed by a new sequence of subjects in solid mechanics to take the place of existing subjects in continuum mechanics and plasticity.

Professor Dean C. Karnopp chaired a divisional committee on automatic control, including Professors Chi-Neng Shen, Ferrell and Wormley, which examined the general role of automatic control in mechanical engineering and recommended establishment of two new graduate subjects, Advanced System Dynamics and Control, 2.151T, and Modern Control Theory and Applications, 2.152T, to be offered for the first time next year.
Professor Shen gave a seminar subject entitled Control Theory and Applications and participated with Professor Karnopp in the teaching of Advanced Control Systems, 2.151.

Professor Wormley made major revisions in Fluid Power Controls and Fluidics, 2.171, that included the introduction of computer-aided design projects and new laboratories involving fluidic system design. The physical space and facilities of the fluid power laboratory were improved and new test facilities developed with the assistance of graduate students.

Professor Ferrell, with Dr. John W. Senders and Professor Laurence R. Young of the Department of Aeronautics and Astronautics, taught Life Support and Human Performance in Manned Systems, 2.181T, in its new 12-unit format. Professors Brown and Rosenberg offered a new subject, Modeling and Simulation of Dynamic Systems, 2.141T. Professor Brown continued development of manuscripts for use in this subject and in his graduate subject, Distributed Systems, 2.153.

Professor Baumann continued to represent the Department in the interdisciplinary systems design subject, Special Studies in Systems Engineering, 2.191J. The project this year was the design of an airport-seaport facility for Boston. An outer harbor airport facility with a renovation of a floating structure to reduce developed-area requirements and the modification of Logan Airport to vertical takeoff and landing systems, as well as a seaport container facility, were presented by the class to representatives from government and industry. The class project report will be published by The M.I.T. Press.

Michael S. Baram, Executive Officer of the Graduate School, offered a new subject, Legal Aspects of New Technology, 2.96. Patent and copyright systems and the practices of Federal agencies were critically reviewed in relation to societal values and technological progress. Case studies regarding promotion and utilization of invention and innovation were presented and much discussion was centered on the impact of new technologies on copyright laws and the author-publisher-information systems-user relationship.

Professor Cravalho, together with Professor Leon R. Glicksman, undertook development of a new subject, Radiation Heat Transfer, 2.58T, which will present the physical mechanisms underlying radiative processes and the techniques of utilizing these mechanisms in the analysis of engineering systems.

Professor Rohsenow joined Professor Bergles in the continued development of Two-Phase Flow and Boiling Heat Transfer, 2.57, now in its second year.

The new subjects, Mechanics and Optics of Polymers, 2.905T, and
Principles of Macromolecular Physics, 2.906T, were restructured by Professor Yannas. The first will carry the basic theory and recent developments in linear and non-linear viscoelastic behavior of polymers; it will also introduce the use of visible and infrared optical measurements in the study of molecular events accompanying linear and non-linear deformation in polymers. The second subject introduces a new statistical mechanical approach to the basic design problem of the relationship between molecular structure and physical properties in polymers.

The subjects in polymers dealing with properties of fibrous materials, Fiber Research Laboratory, 2.912, and with textile processes, Fiber Processing Dynamics, 2.904, were given in seminar form for the first time, with Dr. Edward S. Gilfillan Jr. joining Professor Backer and Dr. Emery I. Valko in staff presentations and frequent critiques of student papers. It was clear that over-all coverage of subject matter was less than that experienced in formal subject presentation, but the depth of treatment of individual topics was increased and student-staff contact enhanced. The method has distinct advantages in “applications” subjects.

A new Polymer Physics Laboratory has been partly equipped to take the place of the former Fiber Microscopy Laboratory. With the expected acquisition of an infrared spectrophotometer and continued improvement in existing facilities for studying mechanical, thermal and optical properties, the scope of experimental studies of polymeric materials will be greatly expanded.

SPECIAL SUMMER PROGRAMS

Again the departmental faculty made strong contributions toward the Special Summer Programs of the Summer Session. The following programs will be offered in the summer of 1968: Photoelasticity and Moiré Techniques, by Professor William M. Murray and experts from industry and universities; Strain Gage Techniques: Lectures, by Professor Murray and outside authorities; Strain Gage Techniques: Laboratory, directed by Professor Murray and presented by a staff from M.I.T., industry, and other universities; Non-Destructive Testing, directed by Professor Murray and presented by members of the M.I.T. staff and various authorities from industry; Physical Measurement and Analysis, directed by Professors Cook and Rabinowicz and presented by members of the Materials Processing and Surface Laboratories; Modern Developments in Heat Transfer, coordinated by Professors Rohsenow and Bergles and presented by other members of the Department and of the Department of Chemical Engineering and outside lecturers; Physical System Dynamics, by Professors Karnopp and Rosenberg and other members of the Department; Structure and Mechanical Properties of Fibers and Semicrystalline Poly-
mers, by Professor Yannas and Dr. Valko, by Professor John W. S. Hearle of Manchester University, and by speakers from industry; Performance Characteristics of Textile Materials, by Professor Backer and Dr. Valko and speakers from industry and other universities; Applied Mechanics of Fibrous Structures, by Professor Percy Grosberg of Leeds University, and Professors Backer, Berg and Hearle and research engineers from industry and government; and Dynamics of Textile Processing by Professor Grosberg, Professor Hearle and Professor Backer and visiting lecturers from industry.

RESEARCH

MECHANICS AND MATERIALS DIVISION

APPLIED MECHANICS Professor Crandall continued investigations in the Acoustics and Vibration Laboratory on the random vibration of complex structures. Studies of the distribution of vibrational energy and the flow of vibrational power were completed. Under the general heading of structural vibration due to seismic, acoustic and aerodynamic excitation, investigations of the acoustic interaction between building structures and solid foundations were begun and a study of the rattling of window sash by sonic booms was completed.

Also in the Acoustics and Vibration Laboratory, Dr. Huw G. Davies is conducting research on the vibration of panels excited by turbulent boundary layers with particular concentration on the effects of modal coupling.

Professor Pierce's research on low-frequency acoustic wave propagation led to papers on acoustic waves in the lower ionosphere and on a line source near a fluid interface. He initiated a program of research on sonic-boom propagation with a paper describing a mechanism for the appearance of spikes on sonic-boom pressure waveforms.

The first physical explanation of the requirement for astatic equilibrium in St. Venant’s principle was given in a paper by Professor Berg. Another study completed dealt with the diffusion of momentum in non-linear viscous fluids and its relation to convection in the earth’s mantle. Professor Berg and his students continued studies on stress corrosion and on the analysis of deformation in metalworking operations. A new research program initiated by Professor Berg is concerned with non-local (long-range) mechanics in composite heterogeneous media with particular emphasis on permanent deformation and fracture.

MATERIALS Professor Egon Orowan and his students investigated the physical basis of adhesion and the mechanism of the yield phenome-
non in iron. They found that the strength of joints with brittle adhesives
is governed by repeated crack nucleation in the glue oblique to the ad-
hesive layer and parallel to the fracture front, while in viscous and visco-
elastic adhesives the strength is governed at low peel velocities by the
resistance of the adhesives to the formation of parallel torques separated
by ridges propagating from the peel front into the glue, and at high peel
velocities by the formation of bubbles ahead of the peel front. In torsion
experiments on thin-walled iron tubes Professor Orowan and his students
found that even when all residual stresses were eliminated the yield
points were absent from the stress-strain curves of reverse deformation
following strain aging. On reverse twisting without an intervening aging
treatment, a Bauschinger overshoot was observed consisting of a rise
of the Bauschinger curve above the lower yield level. From these and
earlier experiments, it was concluded that the yield phenomenon of iron
does not arise from unlocking of carbon or nitrogen locked dislocations,
but is due to the limitation of the free run of dislocations between ob-
stacles, such as grain boundaries, which demand a higher stress for dis-
location multiplication over the limited free run and due to the drop of
the shear resistance of such obstacles once they are broken through by
a dislocation pile-up. Thus considerable drop is found to be a conse-
quence of pencil glide in iron.

Professor Murray and his students continued their experiments on
the Fatigue-Life Gage, which is used as a sensor for determining cumu-
lative fatigue damage, and broadened their investigation of stresses in
connections of cylindrical members for off-shore oil drilling rigs and
the like. The research projects in connection with development of aids
for teaching experimental stress analysis were also continued.

Professor Frank A. McClintock and his students continued their plas-
ticity analysis of stress and strain around inclusions and other inhomo-
genities and performed experiments to establish ductile fracture cri-
teria in structures and metal forming processes. In experiments with
the scanning electron microscope they found a striking similarity in the
fracture of many ductile metals, where hole growth plays a prominent
role. Although good agreement was found between theory and experi-
ment for the growth of a single cylindrical hole in shear, the experi-
mentally observed ductilities fell short of the predictions of the con-
tinuum mechanical analysis. Two computer analyses of plastic flow are
being developed, one based on adjusting the displacements to minimize
a scalar measure of the force imbalance and the other on a superposition
of dislocation dipoles to satisfy the yield criterion and flow rule. In addi-
tion, computer routines developed elsewhere are also being used when-
ever applicable.
Professor Ali S. Argon and his students continued on the one hand with their experiments on the fatigue mechanisms in semibrittle materials, and on the other hand with their experiments and theoretical analysis of laminar slip in copper crystals. In lithium fluoride single crystals, widespread fatigue damage in the form of pore formation and growth was found at 500°C throughout the volume. Such holes coalesced along deformation-induced tilt boundaries, producing cracks. Although the observed pore damage was strongly linked to diffusional processes, its development required a temperature above that at which cross slip became profuse. Production of visible pore damage was preceded by a steady reduction of density from the start of the experiment. From these observations it was decided that the damage was due to the accumulation of vacancies by diffusion. These vacancies were produced steadily by the cyclic plastic deformation made possible by the elimination of internal stresses by cross slip. Crack growth rates were studied on silicon-iron specimens by measuring the increasing compliance of a fatiguing specimen; these measurements are being complemented by scanning electron microscope studies of the actual fracture surface. The latter experiments show profuse crack branching out of the main fracture surface. The statistical theory of laminar slip in copper crystals developed earlier was refined by considering in detail the mechanisms of breakaway of segments of dislocations in multipoles and their effect on source formation probabilities. The new stress-strain curves calculated with these refinements agree very well with experimental stress-strain curves of copper single crystals.

MATERIALS PROCESSING AND SURFACE LABORATORY
The study of mechanical reliability continued under the direction of Professor Rabinowicz. Novel methods were developed for predicting the lives of mechanisms by extrapolation from results obtained under accelerated conditions, and these methods were found effective for mechanisms as diverse as electric drills, light bulbs and ball bearings. Attempts are being made to extend the results to systems which can be overstressed in more than one way, for example, by increasing their temperature and by mounting them in a mechanical shaker.

Professors Nayak and Cook made significant progress towards understanding the wear mechanisms for cemented carbide cutting tools at high temperatures. Performance of these tools was correlated with the thermodynamic stability and growth kinetics of surface oxide films. Autoradiographic studies show that the wear process occurs on a scale smaller than one micron. Investigations of thermally activated chemical
reactions between chip and tool materials are presently under way. These results will be used to develop quantitative models of tool wear.

Professors Cook and Nayak made progress in understanding the rate limiting mechanisms in electrochemical machining. Their explorations include the use of elevated pressure, pulsed power supplies and fused salt electrolytes.

Professor Cook's activity in computer-assisted production planning reached the point at which optimal manufacturing methods can be determined for very simple parts. Work on the control of machine tool vibrations through active systems is progressing.

Professor Syniuta continued studies of rolling contact element fatigue with the objective of discovering the reason for and the origin of micro-cracks leading to fatigue failure. Both electron transmission and scanning microscopy are used in studying fracture surfaces to determine the direction of crack propagation. The presence of some polar complexes in lubricants was shown to affect the life of a bearing greatly. This phase of research is being investigated by conducting a series of polarized tests. Professor Syniuta is conducting preliminary work on a new technique for machining glass, using a form of electric discharge machining.

Professor Brandon G. Rightmire continued work on boundary lubrication under approximately thermodynamic-equilibrium conditions, for which a simple theoretical model based on interfacial adsorption is being tested experimentally.

FIBERS AND POLYMERS
Professor Yannas studied the strain-limit of applicability of linear visco-elasticity theory over a range of temperatures, experimenting with amorphous polycarbonate. Considerable attention was given also to the possible equivalence between devitrification and the necking of a glassy polymer, such as quenched-amorphous Mylar film. Experiments over a three-year period by Professor Yannas led to an indirect determination of the vitrification temperature of water \((-146 \pm 4^\circ C)\), that is, the temperature below which water presumably exists as a brittle, amorphous glass.

Professor Backer continued study of flexing mechanisms in fiber assemblies, elucidating the complex interaction between viscoelastic properties of fiber components, structural geometries, and frictional conditions. In the processing area, emphasis was given to the mechanisms influencing fiber motion during drafting operations. Development work on an Information Retrieval System for Textile Information continued with major effort devoted to preparation of a second thesaurus edition for language control in international textile information systems.
Dr. Valko and Dr. Hans U. Rudolf were most active in these information studies, while their experimental efforts were devoted to determining the effect of crosslinking on the diffusion of dyestuffs into fibrous materials.

THERMAL AND FLUID SCIENCES DIVISION

THERMODYNAMICS In collaboration with Professors Tau-Yi Toong, Augustus R. Rogowski and John P. Appleton, Professor James C. Keck initiated a basic study of the production of air pollutants in combustion processes. The major source of such pollution is the internal combustion engine; in spite of broad public interest in this problem created by our technological age, vigorous efforts for support of research on automotive pollution have had discouraging results. During the year one Master's thesis was completed in this area, and at present two doctor's and two Master's candidates are working on the problem.

Professor Keck continued theoretical research on the kinetics of both homogeneous gas-phase and heterogeneous gas-surface interactions, resulting in the completion of three papers: one on the scattering of atoms from surfaces; a second on the dissociation and recombination of moderately complex molecules; and the last on the excitation and ionization of atoms by electron impact.

Professor Appleton in collaboration with Dr. Thomas I. McLaren is about to initiate experimental studies of high-temperature gas phase reaction kinetics in shock tubes; the shock tube facility to be used is virtually completed. One of the initial studies to be carried out will be aimed at understanding collisional de-excitation processes — that is, atomic and radical recombination, vibrational de-excitation, and so forth, in the gaseous environments encountered in re-entry flows and in the cylinder and exhaust systems of internal combustion engines.

Interactions of gases with solid surfaces continued to be the principal research interest of Professor Robert E. Stickney. Experimental studies motivated by thermionic energy conversion yielded precise data on the work functions of various refractory-metal surfaces partially covered with adsorbed cesium or oxygen atoms. In a complementary study, a theoretical treatment of high-temperature oxidation of tungsten was developed; the results obtained agree satisfactorily with existing data.

Dr. George N. Hatsopoulos, jointly with Professor Elias P. Gyftopoulos of the Department of Nuclear Engineering, compiled a manuscript for Part I of a book entitled Thermionic Energy Conversion. He also completed the formulation of a general theory of quantum statistical thermodynamics and successfully applied it, with Professor Gyftopoulos, to derive an exact and general expression for orbital electronegativity.
CRYOGENICS LABORATORY

Professor J. L. Smith Jr. continued work on a variety of problems in the field of cryogenics:

1. In cooperation with Professor Herbert H. Woodson, of the Department of Electrical Engineering, the effort in the application of cryogenics to the electric power industry has centered on the construction of a synchronous generator with a rotating superconducting field. The rotating dewar vessel has been completed and has spun liquid helium at 3,600 rpm. The superconducting winding is complete and awaiting testing.

2. A study of the influence of nuclear radiation on boiling heat transfer to liquid helium showed that small amounts of nuclear radiation have a significant influence by augmentation of bubble nucleation.

3. The 2,500 cfm vacuum system for pumping on liquid helium was completed. The first experiment to use this facility is an investigation of the distillation process in an He³—He⁴ refrigerator.

4. An experimental Stirling engine refrigerator was completed and will be used to verify the thermodynamic analysis developed in several previous theses.

5. Work continued on the freeze-out of impurities from the gas stream passing through a thermal regenerator, the application of metal bellows to cryogenic refrigeration systems, and the spontaneous thermally induced oscillations in liquid-helium lines.

6. Work was completed on a survey of the properties of O₂—N₂ mixtures.

Professor Cravalho studied the propagation of thermal radiation in highly absorbing media. In conjunction with this effort, he initiated research on the experimental measurement of radiation properties of metals at cryogenic temperatures. A project to investigate the influence of freezing and thawing rates on the preservation of biological specimens at cryogenic temperatures was begun.

The facilities, equipment and experience of the Cryogenic Engineering Laboratory continue to be available to and well utilized by the M.I.T. community. Instrumentation for the Laboratory was modernized and increased significantly during the year. Cryogenic liquid facilities were expanded by the acquisition of additional liquid nitrogen and liquid helium storage containers.

FLUID MECHANICS

Professor Ascher H. Shapiro, working with Professor Michel Y. Jaffrin, carried forward work in peristaltic pumping. Detailed calculations were made of the reflux phenomenon (which seems to be relevant to ureteral
function) and of a trapping phenomenon in which a large bolus of liquid is convected as a parcel at the wave speed. A new experimental apparatus is near completion.

In collaboration with Dr. Colin Clark and Professor Jaffrin, Professor Shapiro continued work also on the aortic balloon technique of left ventricle assistance. The experimental system is completed. Preliminary studies show that the simple limp balloon inflates with an undesirable shape, hence some mechanical constraints are necessary.

Professors Ain A. Sonin and Ronald F. Probstein started a theoretical and experimental research program in electrodialytic desalination of sea water. Results from this program showed the proper scaling parameters for such systems, which appear to enable designs of much higher performance than achievable at present. Professor Sonin continued laboratory experimentation in rarefied plasmadynamics, simulating in a wind tunnel various problems associated with the interaction of a satellite with the earth's ionosphere.

Professor Probstein extended his research in the vacuum-freeze process of desalting sea water and by means of laboratory experimentation on a new type of wash column showed that the cost of this process can be reduced greatly. Plans for incorporating the ideas into an actual pilot plant are under way. He also undertook a theoretical study of high intensity explosions in the atmosphere; the results eliminate much of the uncertainty now existing as to the effects of such explosions. He also continued theoretical studies on hypersonic, low-density flows and on dusty-gas flows.

Professor David P. Hoult began a study of engineering methods for controlling and collecting large oil slicks on the open ocean. From this study came a better understanding of the diffusive character of random wave fields, and several ideas for practical devices to contain oil slicks.

Studies of the aerodynamics of plumes from high stacks were continued by Professor Hoult in collaboration with Professor James A. Fay and Dr. Marcel P. Escudier. They were successful in simulating the plume from a high stack in a simple laboratory experiment. Dr. Escudier took high-speed motion pictures of plumes produced with a scaled model "smoke" stack towed through a water tank which give a convincing visual demonstration that the correct scaling laws are being obeyed. A semi-empirical theory was developed which correlates the secondary flow in a plume with the rate of fluid it entrains.

A stratified-flow wind tunnel will be required for a more complete simulation of the interaction between a smoke plume and atmospheric
conditions — in particular stratification and shear. A design study indicated the feasibility of building a device of reasonable size.

Professors Fay, Keck, and Hoult are also studying certain problems of air pollution in conjunction with the Harvard-M.I.T. Joint Center for Urban Studies.

Professor Fay, in cooperation with the Maine Department of Sea and Shore Fisheries, studied the use of bubble screens to permit the use for agricultural purposes of the warmed coolant water discharged from power plants. He continued his studies of instabilities in magnetoplasma-dynamic arcs and, in conjunction with Dr. Yeshaiahu Y. Winograd, the structure of magnetically balanced arcs. These studies supplied scaling laws for the design of practical devices incorporating arc discharges.

Research on air pollution was initiated this year by Professor Toong with the main emphasis on formation and elimination of nitric oxide and carbon in combustion. Professor Toong also continued research on instabilities in exothermic hypersonic flows, acoustic-flow interactions, acoustic waves in reactive flows, chemi-ionization and chemiluminescence in gaseous detonations, and dynamic contact angle.

HEAT TRANSFER

Professor Rohsenow, with the aid of Eugenii D. Fedorovitch, continued research in condensation and boiling of liquid metals and on film boiling of nitrogen in forced flow. A logical modification in the theory led to a very marked improvement in our ability to predict heat transfer from condensing liquid metals.

Professor Griffith observed that the deteriorated heat transfer occurring at supercritical pressure and high heat fluxes is due to a combination of low wall eddy diffusivity and low core velocity. The dropwise condensation investigation uncovered the fact that commonly used promoters can contaminate the drops and drastically reduce the heat transfer rate. Investigation of bubble growth rate at low pressure uncovered the fact that dynamic limits are governing and interface mass transfer limits are of negligible importance. Analysis of the unsteady momentum fluxes showed they are in a frequency range and of sufficient amplitude to cause harmful vibrations in reactor fuel elements.

Professor Glicksman continued his research on simultaneous convection and radiation heat transfer in absorbing media; an apparatus to model the case of a gray gas is being constructed. The principle of superposition is being used to measure the thermal conductivity of the media at elevated temperatures. Research was initiated by Professor Glicksman on the effect of the environment on the radiation heat transfer
to boiler tubes. His research on the mechanics of fiber drawing continues; it was shown that variations in the strength of glass fibers reported in the literature can be explained by a proper calculation of the cooling times for the fibers.

Professors Glicksman and Rose developed a statistical analysis for the drop size distribution in dropwise condensation; this is a prerequisite to the theoretical calculation of heat transfer during dropwise condensation.

Professor Bergles continued work with the Francis Bitter National Magnet Laboratory on cooling of high-field electromagnets, with emphasis on subcooled flow boiling. Detailed visual and electric probe observations were made of the burnout condition, and a model developed to describe the onset of burnout. A study of acoustic velocity in flowing two-phase mixtures was completed. Analytical and experimental studies of flow oscillations in parallel heated channels are being continued. An experimental study of the direct-contact heat transfer process in spray towers was completed. A comprehensive survey and evaluation of techniques to augment convective heat and mass transfer was prepared. Augmentative techniques investigated were tape-generated swirl flow, internally finned or roughened tubes, and boiling from surfaces with non-wetting spots.

Professor Borivoje B. Mikic continued research in the field of thermal contact resistance; the effects of plating and the contact resistance through bolted joints were investigated. His investigation of constriction phenomena in dropwise condensation showed that this effect could be a significant factor in this type of heat transfer. He also developed an analysis for growth of bubbles at a heating surface and a new correlation for pool boiling heat transfer.

Professor John S. Maulbetsch continued work on condensation of vapors in forced convection flows.

Mr. Fedorovitch participated in research on forced-flow film boiling and on metal-vapor condensation projects. He worked on the problem of comparison and generalization of experimental film-boiling data for different media, which is aimed at understanding the mechanism of phenomena better and which will help in predicting actual parameters (temperature, quality, heat transfer coefficient) for non-equilibrium post-burnout flow in heat exchange equipment. He also participated in experiments on nitrogen-flow film boiling and on the measurement of Leidenfrost force for nitrogen droplets which strike an inclined hot plate. Concerning the problem of film condensation of metal vapors, he studied the interface thermal resistance, taking into account the vapor-subcooling effect near the condensate surface due to heat conduction.
Professor John W. Rose carried out theoretical investigations into certain aspects of drop and film condensation and assisted in the projects on liquid metal condensation and drop condensation.

GAS TURBINE LABORATORY AND SLOAN AUTOMOTIVE LABORATORY
Careful experiments with a transonic compressor wheel indicate that the drag increase near a relative Mach number of unity is several times larger than the wave drag predicted by theory.

Knowledge of the effect of a favorable pressure gradient on the behavior of a turbulent boundary layer was extended into the compressible domain and to higher Reynolds numbers. The region where a turbulent boundary layer reverts to laminar was more fully defined.

Hot-wire measurements of turbulence intensity and Reynolds stresses in a boundary layer with the pressure gradient adjusted to give zero wall friction are nearing completion.

Careful flow and power measurements are being obtained to compare a compressor with conventional blades with one which has unconventional blade shapes that have previously given promising preliminary results.

Flow-visualization studies of radial-flow turbine and compressor blading are progressing.

The developing flow in a rectangular channel rotating about a transverse axis is being studied in an attempt to improve understanding of centrifugal pumps and compressors.

The significant effect of a small amount of swirl on the turbulent mixing of an axisymmetric jet is being measured and a predictive theory is being extended.

The size of condensing droplets in an expanding flow is being measured by light-scattering techniques.

An investigation of the flow regimes in axial-to-radial diffusers was started.

A theoretical and experimental investigation of the flow of a turbulent boundary layer over fences of varying heights was begun.

Another investigation in the initial stages concerns the effects of time-varying energy addition on the separating and diffusing characteristics of turbulent boundary layers.

A method for testing large turbomachines on site was designed and tested and found to be very promising.

SYSTEMS AND DESIGN DIVISION
Professor Robert W. Mann and his students continued research and
development on artificial limbs, cybernetically connected to the neuromuscular system of the amputee. The proportional rate, force-sensing, electromyographically controlled prosthetic elbow underwent major electronic and electromechanical redesign. Laboratory evaluation on several amputees indicated ability to control limb flexure in a natural way within minutes of first fitting. This was a collaborative bioengineering effort including M.I.T., orthopedic surgeons from Harvard Medical School and Massachusetts General Hospital, and the staff and facilities of the Rehabilitation and Research Centers of the Liberty Mutual Insurance Company. Under Professor Mann's supervision a doctoral thesis explored and proposed a novel method for providing an amputee with supplementary cues on elbow angle using a tactile display on the amputee’s stump. Another graduate student developed a proportional control system for an electric wheelchair operated by a quadriplegic patient.

In collaboration with the Massachusetts General Hospital, Professor Mann supervised continuing work on the analysis of ultrasonic energy as a means of brain and spinal cord surgery. A doctoral student completed a thesis which, for the first time, provides a mathematical model correlating ultrasonic system configuration and input variables with the location and size of lesions created in nervous tissue.

Professor Mann also supervised exploratory work in the feasibility of using acoustic propagation and attenuation to measure quantitatively the constituents of cellulose fiber in water suspensions used in paper making.

Dr. James B. Morrison carried on research in the mechanics of locomotion to determine the relation of muscle force to muscle length and velocity of contraction during locomotion. This is one of the first investigations to consider forces and energy transfer as well as kinematics.

Dr. Philip A. Drinker continued his work on the development of equipment for use in the respiratory care of critically ill patients. A new air-oxygen mixing valve for providing controlled oxygen mixtures was developed to the production stage by Dr. Drinker and four undergraduate mechanical engineering students. Work continued on a new blood oxygenation system using helically coiled membranes which includes new methods of enhancing gas transfer rates and minimizing blood damage.

Professor Baumann continued development of the Braille-computer translation system for preparation of Grade Two English Braille via computer. A student thesis, conducted in cooperation with the Perkins School for the Blind, demonstrated the use of a time-shared console for translation of typewriter English input into Braille output. Work is continuing on further evolution of a Braille belt display system, and a version
utilizing a magnetic cartridge as the primary memory is being developed. A facility for the translation from mono-type paper tape to magnetic computer tape was completed.

In the area of high-density graphic storage, one of Professor Baumann's students succeeded in making one-tenth-micron holes in one-tenth-micron thick carbon deposited on glass, by means of a laser. They are now investigating the feasibility of a high-density memory using these techniques.

Our program in the area of urban and intercity transportation systems continued active. Professor Richardson carried forward research on vehicle-guideway suspension dynamics with emphasis on the dynamics of fluid-suspended vehicles operating at high forward speeds. Two doctoral, three Master's and one Bachelor's theses were completed under this program dealing with the dynamic modeling and performance optimization of fluid suspensions. Proper use of positive pressure feedback in fluid suspensions was found to effect dramatic improvements in potential passenger comfort.

Research on active suspensions for high-speed vehicles and on metal-to-metal rolling contact of a wheel on a rail continued under Professor Paul's direction. This work resulted in a new theory of rolling contact which was proposed this June by Pangal R. Nayak in his doctoral thesis.

Professor Brown continued experimental and theoretical research on fluid-wave propagation with applications to the behavior of high-speed vehicles in tunnels. Professor Wilson continued research on the flow phenomena occurring when a fast train enters a tunnel. A doctoral thesis is currently under way in which Mach and Reynolds number similarity is obtained by driving an asymmetric model into an atmosphere of Freon. A theoretical approach is being developed which will attempt to predict the pressure history on the front and sides of the vehicle.

In the field of urban transportation, a study was held in the summer of 1967, supported by the General Motors grant to M.I.T., which considered the possibility of various automated dual-mode urban transportation systems. Professors Wilson, Paul and Baumann participated, with faculty from several other departments. Professor Wilson and his students continued work during this academic year on the design and evaluation of a palleted dual-mode system capable of transporting vehicles, passengers, and containerized freight between urban centers. A Master's thesis in process is considering detail design of certain critical components and is investigating experimentally the stability of pallets on the guideway. Professor Baumann's students continued investigation of dual-mode automated automobile systems and began the design of a control
system utilizing a standard automobile as the vehicle. Power supplies, steering systems, and speed control systems were designed; a number of innovations in steering control are being investigated. A preliminary cost analysis was made and a structural design was undertaken to determine the cost and acceptability of elevated, on-grade, and sub-grade structures. This dual-mode activity was initiated five years ago by Professor Baumann as a senior student project; it then became a junior project, a graduate student project, and most recently has been studied under sponsorship of the Department of Housing and Urban Development by eight U.S. corporations. At M.I.T. the stages of hardware development necessary to implement a full-scale system are currently being outlined.

Professor Wilson continued research in highway safety. A method was developed for optimum resource allocation of transportation funds applicable to a region for which accurate accident data are available. Methods of reporting traffic accidents were evaluated by a Master's thesis student who is working as a mechanical engineer in a multidisciplinary team, headed by Dr. Luongo of Boston University, which is investigating fatal accidents in the Boston area. Other research, which resulted from experiments and cost-benefit analysis on various types of semirigid and energy absorbing bumpers, included formulation of recommended regulations for the Interstate Commerce Commission to prevent rear underrun accidents between cars and trucks.

In the Man-Machine Systems Laboratory, Professors Sheridan and Ferrell continued research on remote manipulation using a laboratory computer-manipulator and driving and control of semi-automatic highway vehicles. Professor Ferrell investigated decision making in manual control, driver behavior in automatic transportation systems, the effect of preview on human information processing rate and remote manipulation with long delay times.

Professor Daniel E. Whitney developed methods for providing an operator with natural separable control of a remote manipulator both with and without a computer in the control loop. Dr. Senders conducted research on the driving simulator involving both speed control and steering behavior.

Considerable interest has developed this year regarding application of technology to developing countries. Professor Wilson and his students investigated the use of a Stirling Engine and a sun-following mirror system as a possible power plant for developing countries, and made an experimental study of windmill design. Two windmills were built and tested; the first was a reproduction of a full-scale Savonius rotor and the
second was an axial-flow machine with an automatic feathering device. Under Professor Baumann, a student from India and subsequently a senior thesis student completed development of a low cost, two-plow tractor to be built in underdeveloped countries from automobile scrap. It was found that the required scrap parts could be obtained on site for approximately $100, that approximately $300 worth of new parts would be necessary, and that the system would be producible with a capital investment of $2,000 for manufacturing facilities. The resulting machine is equivalent to a $3,000 commercial tractor.

Research on fluidics and fluid-power control continued actively. Professor Richardson and his students completed research in hybrid fluidics and investigated a novel pneumatic acceleration sensor and a vortex-amplifier actuated hybrid switching valve. Professor Wormley completed a basic investigation of vortex valve characteristics resulting in a design procedure for valves operating in the incompressible flow regime and an analytical model which includes the effects of secondary flow in the end wall boundary layers of short chambers. Professor Wormley’s students completed several studies relating to fluid amplifier performance. Professor Brown continued research on fluid line dynamics and extended the general method of characteristics to certain classes of non-hyperbolic partial differential equations. He continued research on the dynamic identification and modeling of a proportional fluid jet amplifier.

Professor Douglas P. Adams investigated nomographic organization of mathematical relationships for computer use and demonstrated substantial computer time savings over the conventional Newton-Rhapson Method. Investigation continued in kinematics on the use of computer-plotter techniques for representing in contour form loci or equal values of numerous variables along four-bar coupler-paths of optimum straightness. He continued translation of the definitive work of I. I. Artobolevskii.

With his colleagues and students, Professor Paynter continued research on the dynamics and control of rotating electrical machines. A novel alternative theoretical treatment was developed which facilitates analysis and simulation of machines either operating under unbalanced and saturating conditions or built so that the air-gap field has sensible harmonic content. A program was written and used successfully which permits digital simulation of the generalized four-winding rotating machine, operating alone or in interconnected systems. Finally, new promising methods of two-axis excitation control of synchronous machines were conceived and tested.

Professors Karnopp and Rosenberg published a monograph, entitled *Analysis and Simulation of Multi-Port Systems—The Bond Graph Ap-
approach to Physical System Dynamics, which evolved from their special summer subject, Physical System Dynamics, 2.22s. This book sets forth the present state of research results in system dynamics which followed Professor Paynter's invention of bond graphs almost ten years ago. Professor Rosenberg developed two new versions of the ENPORT family of computer programs designed in FORTRAN for the IBM 1130 computer which will simulate linear and non-linear physical system responses. Professor Karnopp continued research in random vibrations, active control of vibration, analysis and simulation of physical systems, and active vehicle suspension schemes.

Professor Steven A. Coons continued research in computer-aided design and completed a monograph, entitled Surfaces for Computer-Aided Design of Space Forms, published by Project MAC.

CENTER FOR SENSORY AIDS EVALUATION AND DEVELOPMENT

The Center announced that, for the first time, a novel would be published in Braille simultaneously with the ink print version. The usual lag is a year or more. Rapid translation into Braille is made possible by the DOTSYS computer programming system developed by the Center. This uses as input the type compositor's tapes used for ink print publication. Economies in Braille production are also expected because it is estimated that two-thirds of the total cost of computer translation is associated with the initial key-punching of the ink-print version into a format compatible with the computer.

Production redesign of the M.I.T. Braille embossers is progressing with the assistance of design engineers from the Instrumentation Laboratory.

The M.I.T. folding cane for aiding travel of blind persons was enthusiastically received at the Blind Mobility Conference. A program for large-scale national evaluation is under way.

DEVELOPMENTS IN COMPUTATIONAL FACILITIES

During the past year the Department underwent a substantial transformation relative to computational facilities. Late in the fall an IBM 1130 digital computer was placed in the Department as part of the Information Processing Services complex. This is operable as a stand-alone machine for local use and it is also now connected via a high-speed data link to the central M.I.T. Information Processing Services Center. This machine is the first operational node of the evolving distributed-computation complex being developed at the Institute. Later in the year, the existing Philbrick analog computer was replaced by a modern solid-state analog
computer, capable of hybrid operation with the digital machine. A small analog-to-digital converter was developed cooperatively with the Department of Naval Architecture and Marine Engineering and has seen active use for reduction of data taken on analog tape.

Development of the new computer complex was carried out under the direction of Professor Richardson who acted as Chairman of the Departmental Computer-Aided Engineering Committee. Professor Adams, Operations Officer of the facility, was responsible for administration and control of the new equipment. Instructors Richard S. Sidell and Robert C. Sheldon acted as technical supervisors responsible for programming and system development of the analog and digital equipment respectively.

Even in the short time the facility has been in operation, the advantages of local access to a small machine for teaching purposes, undergraduate and graduate project and thesis activity, and as a convenience in computation and data processing have been demonstrated dramatically.

**STUDENT ACTIVITIES**

**AMERICAN SOCIETY OF MECHANICAL ENGINEERS**

Under the chairmanship of David F. Cahn, with Professor Wilson as faculty advisor, the student section was unusually active. It produced a program of technical lectures, discussion groups, panels, films and social events. On several occasions there were two or three events in one week. An ethics committee was formed which arranged a program of case studies and discussions during the fall and winter. The foundation for an engineering-management committee was laid.

The society was honored by the William L. Stewart Jr. Award for contributions to extracurricular life at M.I.T.

**PI TAU SIGMA** This honor society provided at the end of each term the subject and instructor evaluation forms it has traditionally distributed to encourage feedback from students to faculty. It also cooperated with the American Society of Mechanical Engineers (A.S.M.E.) Student Section on its ethics seminars.

**AWARDS**

The following awards were presented in May at the annual Awards Dinner organized by Professor Lent.

The deFlorez Award for outstanding ingenuity in mechanical engineering was won by Henry H. Fuller Jr., and honorable mention went to Dan S. Mark, Thomas Turai, Walter G. Maurer III and Donald T. Scholz.
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Silent Hoist and Crane Company Materials Handling Awards were given by the Wunsch Foundation for the best papers in the field of production, materials handling or machine design related to materials handling. The first prize was divided among William B. Arthur III, Phillip J. Davis, David B. Hiatt, Patrick A. March, Robert G. McGregor, Oliver U. O. Mobisson, Timothy J. Romlein and James C. Smith. The second prize went to F. Gordon Willis Jr. and William B. Zimmerman; and third prize to Kenneth R. Hules, Walter G. Maurer III and Donald T. Scholz.

The Ed Wellech-Corning Glass Works Award, to be given students in conjunction with the subject, Engineering Design and Manufacture, was newly instituted through a presentation by Mr. Wellech. The winners for a manufacturing report were Edward M. Waibel, Bruce M. Kramer, Thomas Mikus and Peter M. O'Farrell. The winners for a design project were Robert L. Jeffcoat and Brian H. Mackintosh.

An American Society of Mechanical Engineers certificate for outstanding efforts and accomplishments in behalf of the M.I.T. Student Section of A.S.M.E. was presented to David F. Cahn for the second year.

STAFF

NEW MEMBERS OF THE FACULTY

Dr. John P. Appleton, previously Senior Staff Research Scientist in the Aerospace Department at AC-Electronics Defense Research Laboratories, joined the staff as an Associate Professor. His major field of interest is high-energy gas dynamics involving thermodynamics, statistical mechanics, chemical kinetics, plasmas and fluid mechanics.

Dr. Michel Y. Jaffrin, formerly a Research Engineer at the Centre de Recherches de la Compagnie General d'Eléctricité, joined the Department as an Assistant Professor. His interests are fluid mechanics, plasma physics, lasers, and biomedical fluid mechanics and their application to space science.

Dr. Richard A. Moss came to the Department as an Assistant Professor after receiving his doctorate from Princeton University. He is principally associated with the Heat Transfer Laboratory but will also participate in activities of the fluid mechanics and thermodynamics groups.

Dr. David N. Wormley was appointed Assistant Professor after receiving his doctorate from M.I.T. His major interest is electromechanical fields and control systems.

New Research Associates and their areas of interest include Dr. Huw G. Davies, theoretical and experimental programs on flow noises and random vibrations; Dr. Marcel P. Escudier, fluid mechanics; Dr. Thomas
I. McLaren, fluid mechanics; Dr. James B. Morrison, bioengineering; and Vito A. Proscia, sensory aids for the blind.

John W. Senders, a Senior Lecturer and Research Associate at Brandeis University, was appointed Senior Lecturer and worked with our Man-Machines Group.

RETIREMENTS

Dr. Egon Orowan, one of our most distinguished faculty members, came to the formal age of retirement this year after serving in this Department as Professor since 1950. His earlier career was in industry in his native Hungary and as an academic at the University of Birmingham and at the Cavendish Laboratory in the University of Cambridge. Although best known for his pioneering work in the dislocation theory of metals, his scholarly interests have been amazingly broad and fruitful, including the physics of metals, geological events in the earth's crust, and economic history. He has received many international honors. The Department is fortunate that Dr. Orowan will continue to serve half-time as Professor Emeritus.

While formally in the Department of Aeronautics and Astronautics, Professor Edward S. Taylor has in fact served equally as a Professor in the Department of Mechanical Engineering. As the Director of the Gas Turbine Laboratory from its founding until his retirement, Professor Taylor created a laboratory with a style and a tradition that have earned it international fame. Professor Taylor's students, who are leaders in industry and universities the world over, reflect Professor Taylor's lasting contributions as a teacher on a person-to-person basis. His research skills will continue to benefit the laboratory as he continues half-time as Professor Emeritus.

LEAVES OF ABSENCE

Professor Shih-Ying Lee spent the year writing a book, consulting, doing research and giving a series of lectures at the Technical University of Berlin.

Professor Mann’s leave of absence was spent in part on supervising graduate students and research programs, but mainly on problems relating to sensory aids on the local and national level. On the local level, because of the sudden death of John K. Dupress, he served as Acting Director of the Center for Sensory Aids Evaluation and Development.

Professor Sheridan was a Visiting Associate Professor during the spring term in the Department of Industrial Engineering and Operations Research at the University of California at Berkeley and a Visiting Lecturer at Stanford.
Professor Joseph Gerstmann was on leave with a Ford Residency in Engineering Practice at American Electric Power Service Corporation.

**RESIGNATIONS**

Professor Norman C. Dahl, widely known and respected throughout the entire M.I.T. community, resigned in February to become the Deputy Representative of the Ford Foundation in India. He had been on the M.I.T. teaching staff since 1948. As the first leader (from August, 1961, to July, 1964) of the Kanpur program, he made an enormous contribution to the AID-(Agency for International Development) supported program to develop the Indian Institute of Technology. We shall miss him sorely.

Professor Philip G. Hill, who had been on the faculty since 1958, resigned in December to become Professor and Head of the Department of Mechanical Engineering at Queens University.

Dr. Yeshaiahu Y. Winograd resigned as Research Associate to take up a faculty position at the Technion — Israel Institute of Technology.

**DEATH**

The Inaugural Director of the Center for Sensory Aids Evaluation and Development, John Kenneth Dupress, died very unexpectedly on December 29, 1967.

This was a great loss, both professionally and personally. Professor Mann, Chairman of the Steering Committee of the Center, assumed interim responsibility as Acting Director. Thanks to the dedicated efforts of the Center staff and the support of many colleagues nationwide concerned with the welfare of the blind, the Center-sponsored Conference on Braille Research at the American Printing House for the Blind in Louisville, Kentucky, was held on schedule. The proceedings of the Braille and those of the Blind Mobility Conference, completed just prior to Mr. Dupress’ death, were organized and published along with the Center’s annual report. A search for a new Director for the Center culminated in the appointment of Vito A. Proscia, formerly of the MITRE Corporation, as the new Center Director effective June 4, 1968.

**VISITING STAFF**

Vadim I. Alfjorov, from Moscow State University, was a Research Fellow working with Professor Fay in fluid mechanics.

Dr. Czeslaw A. Broniarek, Design Engineer at the Institute of Basic Technical Problems of the Polish Academy of Sciences, spent the year here as a Visiting Engineer. His interest is non-linear vibrations.
Dr. T. Roy Choudhury, Assistant Professor at Birla Institute of Science and Technology, India, spent a half year here as a Visiting Assistant Professor under M.I.T.'s exchange arrangement with Birla. His fields are thermodynamics and internal combustion engines.

Eugenii D. Fedorovitch, a Senior Research Worker at the Polytechnical Institute of Leningrad, was a Research Fellow working with the heat transfer group.

As part of the M.I.T. participation in strengthening developing institutions, the Department appointed as Senior Lecturers for the spring term Edward S. Gilfillan Jr., who worked with the fibers and polymers group, and Robert Z. Hollenbach, who worked with the design group. Both are faculty members at Lowell Technological Institute.

Dr. Suzue Ishii, Associate Professor in the Department of Mechanics at the University of Electro-Communications, Tokyo, arrived in February to be a Visiting Associate Professor and work in the Acoustics and Vibrations Laboratory.

Dr. Ehud Lenz, Dean of the Faculty of Engineering at the Technion — Israel Institute of Technology, was a guest for three months in the Materials Processing Laboratory.

Dr. Yukweng M. Lin, Professor of Aeronautics and Astronautics at the University of Illinois, was a Visiting Professor working with Professor Crandall. Professor Lin’s interests are aircraft structures and random vibration.

Dr. John W. Rose, a Lecturer at Queen Mary College, was a Visiting Assistant Professor in the Heat Transfer Laboratory.

Dr. Chander S. Sharma, also a Visiting Assistant Professor from Birla, spent a month in the Materials Processing Laboratory.

Dr. Chi-Neng Shen, Professor of Mechanical Engineering at Rensselaer Polytechnic Institute, was a Visiting Professor in the field of automatic control.

Dr. Tatsuhiro Ueda, Professor of Mechanical Engineering at the University of Tokyo, spent three months here as a Visiting Professor working with the heat transfer group.

STAFF ACTIVITIES AND AWARDS

Professor Baumann made numerous presentations of his dual-mode automotive-vehicle concept in Washington and Detroit.

Professor Cook continued to serve as Advisor to the Birla Institute of Technology and Science, Pilani, India. He visited Birla briefly this year and plans to spend six months there next year.
During the summer of 1967 Professor Coons delivered a series of lectures on computer geometry at the University of Michigan. He continued part-time as a Research Fellow at the Aitken Center of Harvard University, doing research in the mathematics of shape-descriptive computer graphics.

Professor Crandall served as Secretary of the Applied Mechanics Division of the A.S.M.E. He was a Visiting Professor at the National University of Mexico during the summer of 1967.

In May, Professor Jacob P. Den Hartog delivered five lectures at the Technical University of Berlin as a Visiting Professor.

Professor Fay continued as Chairman of the Plasmadynamics Committee of the American Institute of Aeronautics and Astronautics and as a member of the National Aeronautics and Space Administration Research and Technology Advisory Subcommittee on Fluid Mechanics.

Professor Ferrell is a member-elect of the Administrative Committee of the Institute of Electrical and Electronics Engineers Man-Machine Systems group.

Professor Glicksman became a member of the Fluid Mechanics Committee of the American Society of Mechanical Engineers.

Dr. Hatsopoulos was appointed by the Atomic Energy Commission as U.S. representative to the Liaison Group for the International Committee on Thermionic Energy Conversion. He was also appointed to the National Aeronautics and Space Administration Research and Technology Advisory Committee on Space Power and Electric Propulsion.

In May, Professor August L. Hesselschwerdt Jr. was a guest of the American University of Beirut at their Conference on Environmental Control, and delivered two papers on the utilization of solar energy for space heating and for summer air conditioning.

Professor Karnopp was appointed Program Subcommittee Chairman for the Second Vibrations Conference of the American Society of Mechanical Engineers.

Professor Keck continued to serve as a member of the physics panel of the Air Force Office of Scientific Research.

During the year Professor Joseph H. Keenan served as Visiting Professor at Purdue and Stanford Universities.

Professor Mann was invited to prepare and present papers on the limb prostheses project at the International Federation of Automatic Control Cybernetics Conference in Yerevan, Soviet Armenia; at the Institution of Mechanical Engineers’ Symposium on the Basic Problems of Artificial Prehension, Movement and Control of Artificial Limbs, in London; and at the First Rehabilitation Conference sponsored by the American
DEPARTMENT OF MECHANICAL ENGINEERING

Academy of Orthopedic Surgeons, the Harvard Medical School, Massachusetts General Hospital and M.I.T.

The proceedings of the Conference on Sensory Aids for the Blind, organized and chaired by Professor Mann at the National Academy of Sciences in March, 1967, were edited and prepared for publication as a National Research Council publication. The report and its recommendations were presented to the Committee on Prosthetics Research and Development of the National Academy of Sciences – National Research Council and the Committee on the Interplay of Engineering with Medicine and Biology of the National Academy of Engineering.

Professor Mann was elected a Director of the Catholic Guild for All the Blind and was appointed to the Advisory Council of the National Joint Braille Authority. He was also appointed to another term as a member of the Committee on Prosthetics Research and Development of the National Academy of Science-National Research Council and in July, 1967, was one of the organizers and session chairmen of the Fourth Conference on Engineering Design Education at Dartmouth.

Professor McClintock was an invited lecturer at the International Symposium on Fracture Mechanics at Kiruna, Sweden.

Professor Murray was an invited lecturer in four universities, where he lectured on the subjects of photoelasticity, Moiré techniques, non-destructive testing and strain gage analysis.

Professor Nayak visited Birla in the summer of 1967 to assist in formulating their part of the joint research program in the general area of machine tool wear.

Professor Orowan received the 1968 Carl Friedrich Gauss Medal from the Braunschweigische Wissenschaftliche Gesellschaft for distinguished contributions to the physics of strength and plasticity.

Professor Pierce served as a member of the advisory committee of the Symposium on Acoustic-Gravity Waves held in Boulder, Colorado, during July, 1968.

Professor Probstein continued as a member of the Fluid Dynamics Committee of the American Institute of Aeronautics and Astronautics and became a founding editor of the Journal of Statistical Physics.

Professor Rabinowicz finished a three-year term as a member of the National Research Council's Committee on Basic Research Advisory to the U.S. Army Office (Durham) and was reappointed to a second term.

Professor Richardson was elected to the American Society of Mechanical Engineers' Research Committee on Lubrication and served on their Automatic Control Division Transportation Panel. He attended the International Conference of Hovercraft at Southampton, England, and
visited the evolving hovercraft industries in the United Kingdom as the
guest of the British government and as part of a two-man mission from
the United Nations Transport and Resources Division.

Professor Brandon G. Rightmire is a member of the American So-
ciety of Mechanical Engineers' Research Committee on Lubrication.

Professor Rohsenow was elected a Fellow of the American Society of
Mechanical Engineers and was presented with the A.S.M.E. Heat
Transfer Division Memorial Award at the annual meeting. He continued
as a member of the Communications Board and the Board of Basic
Engineering, A.S.M.E. He also continued as chairman of a panel of the
Hardened Electric Power System Committee and a member of the Engi-
neering Division, both of the National Research Council.

Professors Rosenberg and Karnopp gave several invited presentations
of their film, "Physical Systems Dynamics-Bond Graph Techniques and
the ENPORT Program," to seminar groups and technical meetings.

Dr. Mark Schoenberg, a former Visiting Engineer, received the Borden
prize for "outstanding ability in research" on his graduation from New
York University.

Professor Shapiro was elected a member of the Board of Governors
of the Technion—Israel Institute of Technology and a Fellow of the
A.S.M.E. He continued with film production for the National Committee
for Fluid Mechanics Films.

Professor Shen served as a member of the Steering Committee of the
1968 Joint Automatic Control Conference.

Professor Sheridan chaired a two-day Conference on Mathematical
Models and Simulation of Automotive Driving sponsored by the U.S.
Public Health Service and held at M.I.T. He continued to serve as editor
of the Institute of Electrical and Electronic Engineers Transactions on
Man-Machine Systems.

Professor Prescott A. Smith was elected a Fellow of the American
Society of Mechanical Engineers and was appointed as the A.S.M.E.
member of the U.S.A. Standards Institute Sectional Committee B89,
Dimensional Meteorology.

Professor Emeritus C. Richard Soderberg received the high honor of
being the first recipient of the De Laval Medal, to be awarded every two
years by the Royal Academy of Engineering Sciences in Sweden. On the
occasion of the award Professor Soderberg delivered a paper on "Forty
Years of Turbine Power Developments." Professor Soderberg was also
honored by the King of Sweden with the title, Commander of the Royal
Order of the North Star.

In May, Professor Stickney was a guest lecturer in a short course on
rarefied gas flows and gas surface interactions given at the University of Tennessee Space Institute.

Professor Syniuta served as a member of the American Society for Lubrication Engineers' Abstract Indexing Committee.

Professor Emeritus C. Fayette Taylor was an invited lecturer at the Escola de Engenharia Maria in Sao Paulo, Brazil, in August.

Professor Edward S. Taylor continues to be active with the work of the National Committee for Fluid Mechanics Films.

Professor Wilson was program chairman of the annual Gas Turbine Division Conference of the American Society of Mechanical Engineers and chairman of the Process-Industries Division of the A.S.M.E. He was also chairman of the Boston Chapter of the Volunteers for International Technical Assistance.

ASCHER H. SHAPIRO

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

In the report from the Department of Metallurgy for 1965-1966, I referred to the gradual shift in emphasis within the Department from mineral extraction to physical metallurgy, accompanied by a concurrent broadening of interests from metals alone to materials in general. I felt then that a gradual abatement of interest in extractive metallurgy would cause problems in the future for the steel and non-ferrous producing industries. In particular, developments in Europe and Japan, where a large number of technically trained persons are entering these industries, have been at times significantly ahead of developments in this country. In 1964, Professor Gerhard Derge, of Carnegie-Mellon University, prepared a position paper for the American Institute of Mining, Metallurgical and Petroleum Engineers on the parlous state of process or extractive metallurgy. His main complaint was that lack of funding for research not only made it difficult to attract students, but led to a scarcity of young teachers who were interested in a career in the field. Dr. Walter Hibbard, during his tenure at the U.S. Bureau of Mines, regarded this as a serious problem for the country and took steps to initiate modest funding by the Bureau.

The Visiting Committee for the Department has considered this problem in conjunction with an examination of materials processing in general. Their viewpoint has been that both extractive metallurgy and materials processing represent a readily identified engineering approach in a department that leans toward science. There are other analogies
between these two areas of research — for example, in the applicability of a systems approach to handle large-scale chemical processes as well as complex deformation processes in a continuous rolling mill.

However, the situation is more serious in extractive metallurgy and the Department must move to give a new emphasis to the field. We have been fortunate to have research support from the American Iron and Steel Institute for a number of years, but it has been very difficult to obtain government support. Our best hope is probably to persuade industry that the problem is serious and to enlist their cooperation directly. At the same time we feel that it must be made clear to other universities that we are making a serious endeavor to revitalize the field. To this end, on the advice of the Visiting Committee, we intend to make one or two faculty appointments to strengthen the twin areas of endeavor which constitute modern process metallurgy, process analysis and control, and the more traditional thermodynamics and kinetics of high-temperature reaction systems.

In materials processing, we have been confronted with the question of whether a unified approach to the field is possible or even desirable. It is clear that we have not resolved this question. Interests in processing are to be found throughout the Department — in ceramics, in electronic materials, in mineral extraction and chemical metallurgy, and in the three areas presently thought to constitute our main processing work, deformation, solidification, and joining. It is clear that materials processing can be dealt with successfully only by those who have a sound appreciation for the engineering involved and a feel for the bridge between fundamental studies of structure and properties and the problems of industrial processes which must be designed to take advantage of such studies. In solidification work, for example, the development of high-strength aluminum alloys, and in deformation work, such as the development of processes for texture control or the optimum combinations of strain rate and temperature for most efficient hot working, we see some success in making this bridge. It is not clear, however, to what extent such success arises from an in-depth approach to a particular problem and to what extent such approaches can be regarded as common to other problems.

We do intend to maintain our strength in both materials processing and extractive metallurgy from our own point of view. Whatever we do ought to have a flavor of the Institute itself; it is inconceivable that we would not take advantage of the skills that exist in departments other than our own which could well complement much of the work that we would like to do.
Last year's report dealt with some of the new subjects in the undergraduate curriculum. There have been no further changes in the curriculum during the year, though it is possible, on the basis of experience to date, that there will be some revision in the laboratory work to avoid having seniors take part in two laboratories while they are, at the same time, starting work on their undergraduate theses. This will mean either dropping a laboratory or incorporating it into the junior year. While the project approach to laboratories has proved to be generally popular, it seems to be asking a little too much of students that they engage in a project-type laboratory at the same time that they are working on their theses.

The sophomore laboratories, Materials Research Laboratory, 3.04 and 3.05, attracted a full complement of students in both terms and have proved to be very popular. Professor Harry C. Gatos, who is nominally in charge of the laboratory, has found that the students welcome a chance to meet with him as instructor and have him enlarge on the scope and applicability of the topics that they are studying in their own research projects.

Undergraduate seminars were presented by Professors Gatos and August F. Witt on semiconductor crystal growth, Professor Robert E. Ogilvie on X-ray and electron optics, Professors John Wulff and Robert M. Rose on superconducting alloys, and Professor Nicholas J. Grant and Dr. Bill C. Giessen on splat quenching.

Note should be made here of the change in emphasis in Professor Wulff's freshman elective, Structure and Properties of Materials, 3.09. This six-unit subject deals with selected topics of atomic, molecular, crystal and phase structure of solids. For a number of years Professor Wulff has considered the idea that the subject could become an approach to solid-state chemistry. In the coming year he proposes to introduce a new subject, Introduction to Chemistry of the Solid State, 3.091, a 12-unit subject that would be available to freshmen. While the content differs considerably from the traditional first college courses in chemistry, perhaps the most novel feature is that recitation sessions will be conducted by a number of the tenured faculty in the Department rather than by teaching assistants.

Undergraduate enrollment totaled 58 students, but only ten Bachelor's degrees were awarded, since a number of the students elected to study for a combined Bachelor's and Master's degree.

The Dow Chemical Company prizes for the best undergraduate theses were awarded to James W. Pugh (first prize) and Peter K. Nagata (second prize). The Metallurgy and Materials Prize for the outstanding
junior was presented to Katherine C. Shepard at a meeting of the Boston Section of the American Institute of Mining, Metallurgical and Petroleum Engineers, which sponsors the award. It is pleasant to note that in recent years at least one girl student has been enrolled in each class.

GRADUATE INSTRUCTION

There were no substantial changes in the graduate subjects of instruction during the year, but an attempt was made to clarify the minor requirements, emphasizing particularly that the minor should be study in a field which is clearly not that of the student's thesis. It might, however, be partially satisfied within the Department, in view of the wide variety of subjects which are offered.

Graduate enrollment averaged 156 students (still below the average of the past year or two because of research funding problems in certain areas). Advanced degrees awarded from September, 1967, through June, 1968, totaled nine Master's, three Engineer and 22 doctor's. The figures for Master's and doctor's degrees are down considerably from last year but such fluctuations are to be expected.

GRADUATE RESEARCH

Since the Annual Report of Research in Materials Science and Engineering, prepared by the Center for Materials Science and Engineering at M.I.T., gives a rather complete summary of the graduate research activities in the whole of the Department of Metallurgy and Materials Science, it has been thought desirable to restrict the research report given here to those accomplishments which have been selected by the faculty as among the more significant. This report is, therefore, not to be regarded as complete, and it makes no mention of a good deal of work that is proceeding but has not yet reached the stage of yielding positive results.

PHYSICS OF SOLIDS

Professors Roy Kaplow and Benjamin L. Averbach have determined the structure of amorphous selenium, a material widely used as a photo-conductor with important applications in electrostatic imaging devices and photo-tubes. It has been shown that the amorphous structure contains a large number of slightly deformed Se$_8$ rings, along with some atoms for which the local symmetry is like that in selenium chains. The structure appears to be consistent with recent infrared and Raman data. The experimental X-ray diffraction data were matched with models in which perturbations of atom positions are chosen by a Monte Carlo pro-
The surprising regularity of this short-range structure for amorphous selenium appears to account for its unusual electronic properties.

Professors Averbach and David J. Sellmyer are studying Fermi surfaces in solid solution alloys with the goal of placing theories of alloy formation on a sounder foundation. Cross-sectional areas of the Fermi surfaces are measured, using the de Haas-Van Alphen effect, at temperatures down to 10 K and in fields up to 150,000 gauss. Recent results have revealed new information on the Fermi surface of pure lead and have shown that alloying lead with small amounts of indium distorts the Fermi surface to the extent of producing a new extremal area on the surface.

Professor Sellmyer is also continuing investigations of the Fermi surfaces of ordered alloys and intermetallic compounds with a reasonably small number of atoms per primitive cell. Measurements of the de Haas-Van Alphen effect and high field magnetoresistance are done at the Francis Bitter National Magnet Laboratory. Recent results include measurements of cross-sectional areas and topological properties of the Fermi surfaces of AuSb₂, AuSn, AuAl₂, AuIn₂, and AuGa₂. The major result which seems to be emerging, as more compounds are investigated, is that the nearly free-electron approximation works surprisingly well, even in compounds of rather complex chemical binding. Professor Sellmyer has also continued work on transport properties and magnetism in transition metal alloys. The thermoelectric power, electrical resistivity, and magnetic susceptibility are measured, at temperatures from that of liquid helium to room temperature, on the alloy systems FeAl, CoAl, and NiAl, near and at the equi-atomic composition. The objective of the work is to try to understand the extent to which the electronic structure and properties of these materials can be understood in terms of Hume-Rothery electron compound ideas and to study the fundamental origins of ferromagnetism and antiferromagnetism in metals. Resistance minima as a function of temperature have been discovered in certain of the CoAl alloys and it seems that this behavior may result from electron scattering from localized spin fluctuations.

Professor Keith H. Johnson has made a number of theoretical studies, particularly of the electronic structure of materials. He has developed a new theoretical approach to calculating, from first principles, the electronic states associated with localized crystal defects such as impurities and vacancies. The method is of particular advantage for including the effect of defect clustering and lattice relaxation. Furthermore, it can be implemented for real materials on a large-scale computer without further approximations to the basic formulae. Professor Johnson has also extended the electronic energy-band computer programs to include the
calculation of relativistic effects such as spin-orbit coupling. Applications to simple metals such as lead and to intermetallic compounds such as beta AuZn have been started. The development of a computerized method of searching the Brillouin zone at constant energy for the theoretical electronic states of metals and intermetallic compounds has also proceeded. A mesh of up to 25,000 general points in the zone is within the scope of the procedure and this permits the computer generation of Fermi surface cross-sections at high numerical resolution. Attention has also been given to the calculation of the one electron eigenstates associated with polyatomic molecules and macromolecules of biological interest.

Professor Simon C. Moss and Philip C. Clapp have completed a three-part treatise on correlation functions in alloys. The work has been successful in calculating ordering and clustering behavior of a wide variety of alloys, including CuNi, CuAu and CuPt, and in understanding the energetics of formations of these alloys. The most striking new development in Professor Moss's research is the completion, with the help of Dr. Jozef Graczyk, of the scanning, electron-diffraction instrument which provides velocity filtering of scattered electrons to within 1 ev out of 50, 80 or 100 Kev. Extensive experiments have been done so far on the structure of amorphous silicon and carbon, on polycrystalline aluminum to verify certain predictions of the two-beam dynamical theory, and on plasma losses in aluminum-zinc alloys, which seem to be free-electron-like up to at least ten atomic per cent zinc. At present there is no comparable instrument elsewhere in the U.S.A.

In addition to his work with Professor Averbach on the structure of amorphous selenium, Professor Kaplow has continued his study of the structure of liquids, using low-angle X-ray diffraction and neutron diffraction. Professor Kaplow, in conjunction with Dr. John W. Brackett, has also made further progress in the development of on-line systems for numerical analysis. The present system, MAP, will be replaced with a new system which will be considerably more flexible. Professor Kaplow and Dr. Brackett have also become interested in a teacher-oriented system for writing teaching programs. The point of view is that any teacher-interactive system should require no programming ability from the teacher and should simplify for him the process for developing a logical and self-consistent tutorial session.

Professors Kaplow and Averbach have also collaborated on a study of beryllium and beryllium alloys. They are interested in measurements of inelastic X-ray scattering; this is part of a program on beryllium which includes the effect of pressure on the elastic constants, which are determined by an ultrasonic technique. Consideration of these and other re-
sults will help to indicate whether even the purest beryllium is inherently not very plastic.

**PHYSICAL METALLURGY**

**STRENGTHENING MECHANISMS**  Professor Morris Cohen and Dr. Milan R. Vukcevich have demonstrated that the enhanced diffusivity which accompanies plastic deformation is a real atomic phenomenon and is not due to mechanical mixing. Enhanced diffusivity results from pipe diffusion along moving dislocations rather than through an excess of vacancies in the lattice. With this latest work the long-standing discrepancies among various investigators in the field have been rationalized.

For the first time Professor Cohen has been able to make direct measurements of the nucleation rate in martensitic transformations by the use of quantitative metallography. The results lead to a self-consistent interpretation of thermal and athermal nucleation during martensitic transformations. A new theory of strain hardening has been proposed in order to account for the remarkable strengthening of cubic metals at high plastic strains. The strengthening is directly attributable to the subgrain size and its magnitude varies linearly with the reciprocal of the mean linear intercept. This functional relationship arises because, according to the model, practically all of the energy of deformation goes into the production of dislocations required to yield the over-all plastic extension. In contrast, for regular grain size strengthening, the flow stress is controlled by the activation of dislocation sources rather than by the generation of the total dislocation length; in this case, the strength varies linearly with the reciprocal of the square root of the grain size. The latter is the Hall-Petch relationship which is well established for grain size strengthening, but it has now been demonstrated that it does not apply to subgrain size strengthening.

Professor Cohen's work on splat quenching has revealed, in iron-base alloys, a new phase which has been called the epsilon phase. It is hexagonal, close-packed and appears to be a solid solution of carbon in a hexagonal close-packed allotrope of iron which is otherwise only stable at very high pressures.

Professor John F. Breedis has continued his research on the crystallography and morphology of defect structures of martensite in iron-ruthenium-alloys containing up to 17 atomic per cent ruthenium. Depending on composition, two types of transformation products are observed, a body-centered cubic martensite similar to that found in stainless steel, and a hexagonal close-packed martensite, the latter forming in the more concentrated alloys. The deformation behavior of iron-ruthenium solid
solutions has also been studied to elucidate the mechanisms which control the deformation process. Professor Breedis has also studied the strengthening of titanium alloys and the fatigue behavior of titanium and its alloys. The objectives are to correlate the observed fatigue behavior with the defect substructures produced during cyclic stressing, and to show the dependence of strength on the structure developed through plastic deformation and phase transformations. Enhanced strengths without drastic loss of ductility may be obtained in titanium alloys through either shock deformation or controlled precipitation.

**Phase Transitions in Solids** Professor John W. Cahn has continued his study of the theory of spinodal decomposition. He has been looking at the theoretical basis for selecting ternary additions to raise or lower the reaction temperature for spinodal decomposition in binary alloys. Future work will use the concepts developed in attempts to control the age-hardening behavior of gold-nickel alloys.

Professor Cahn, in studies on phase separation and crystallization in glass, has been using the Kratky low-angle X-ray camera to study the barium silicate glass system. This system exhibits an asymmetric miscibility gap and previous observations have been made by the electron microscope on slices from bulk samples which have been vapor-deposited. The low-angle X-ray studies would permit the first direct comparison between metallographic, or real space, data and its Fourier transform. It is intended that this work will clear up some of the confusion which exists over morphology and decomposition mechanisms.

Professors Cahn and Kenneth C. Russell have made progress in the broad theoretical and experimental investigation of the thermodynamics and kinetics of nucleation in condensed phases. It has been postulated that splat cooling extends terminal solid solubility by quenching the melt below the extrapolated phase boundary to where the single phase solid is more stable than the liquid plus solid. This has been shown to be incorrect by obtaining extended solubility at the zinc end of the cadmium-zinc system, which shows retrograde solubility.

An analysis of the forces involved in liquid phase sintering of spheres has been completed, showing that the usual force balance obtained intuitively is very close to the exact solution. In a collaboration with Dr. Hoffman of the Ford Scientific Laboratory, the Gibbs-Wulff construction has been extended to determine the equilibrium form of a particle at a grain boundary of arbitrary orientation. The fluctuation theory of Von Smoluchowski and Tisza has been used to analyze thermally activated nucleation and coarsening kinetics. It has been shown that, in heterogene-
ous nucleation, the incubation time may be as significant as the steady-
state nucleation rate in determining which of several competing reactions
will dominate.

Professor Russell has been using linked-flux analysis and the principle
of time reversal in a theoretical study of homogeneous nucleation, and
nucleation in grain boundaries in solids. Incubation times and steady-
state nucleation rates have thus been obtained and the former have been
found to be as much as several orders of magnitude greater than indicated
by earlier calculations. Professor Russell, in collaboration with Professor
Philip G. Hill of the Department of Mechanical Engineering, has com-
pleted some work on nucleation in nozzles. The quantum statistical
theory of Lothe and Pound has been found to apply to the nucleation
process in all vapors except steam. Only a special class of fluids, of which
water is one, behave according to the classical nucleation theory of
Becker and Doering.

HIGH-TEMPERATURE METALLURGY

Professor Grant and his group have made significant progress in under-
standing the mechanism of strengthening and the nature of the high-
temperature stability of oxide dispersion-strengthened alloys. Such
materials offer great potential for improvements in high-temperature per-
formance, but still require extensive study to develop the optimal structure
which will produce the best properties. The work to date indicates that
storage of deformation energy is the most important single feature of
strengthening and that a grain boundary structure composed of very short
grain boundary segments stabilized by oxide particles accounts for the
high-temperature stability of these materials.

An important contribution to the technology of hot working metals has
been made by a refinement technique which might be called the step-
strain method. The technique is applied to cast ingot structures which are
very coarse-grained and hot deformation is carried out in a series of
small steps, each of which is followed by a period to allow for recrystalli-
zation. This work has demonstrated that one can effectively cold-work
metals at high temperatures provided the rate of straining is very high. It
is this cold work that leads to the grain refining reaction and the large
improvements in hot plasticity.

ELECTRON OPTICS

Professor Ogilvie and his group have made diffusion experiments in the
silver-copper-zinc and silver-aluminum-zinc systems. The third compo-
nent, zinc, was diffused into the alloy single crystals from the vapor phase.
The crystals were bent to different radii around an axis parallel to the 211 plane to introduce different concentrations of edge dislocations. The influence of the dislocations was investigated by measuring the penetration of the zinc. The scanning electron microscope reported on last year has been supplemented by a purchased Cambridge Instrument microscope which has superior stability and resolution. This is being used for a large number of projects, both within and without the Department.

Professor Ogilvie has continued his studies of craters and ejecta produced by hypervelocity impact. Craters have been formed in metals from projectiles traveling at 19.2 kilometers per second down to 2.7 kilometers per second. Sections taken through the craters have been studied by the electron microanalyzer and the scanning electron microscope. A study of metallic meteorites has also been continued, with particular attention being paid to the Widmanstatten pattern. The plessite areas in metallic meteorites are being studied with the scanning electron microscope and the presence of martensite with a particular habit plane has been confirmed.

Under Professor Ogilvie's supervision, two dental students have been studying the topology and chemistry of rats' teeth, with the scanning electron microscope and the electron microanalyzer. The objective of the work is to investigate the role of various minerals, introduced in the rats' diet, on the structure of the teeth and the development of dental caries. The distribution of fluorine is, of course, of considerable interest.

Professor Thomas O. Ziebold, in a joint program with the Department of Nuclear Engineering and in cooperation with the Naval Research Laboratory, has started work on the fracture behavior of vessels used for nuclear reactor pressure vessels. The principal research tool is the scanning electron microscope, which makes possible the examination of bulk fracture specimens. The instrument is to be used in the examination of irradiated steel, in an effort to correlate fracture appearance with the reduction of fracture toughness produced by neutron irradiation.

THERMODYNAMICS IN METALLIC SYSTEMS

Professor Michael B. Bever and Dr. Akshaya K. Jena have carried out an investigation of splat-cooled gold-antimony alloys in collaboration with Professor Grant and Dr. Giessen. The work has shown that measurement of thermodynamic properties can contribute to an understanding of the conditions under which metastable phases form. Similar research on splat-cooled phases in the gold-tin system is now in progress.

The thermodynamic and other properties of silver-rich, silver-magnesium and silver-cadmium solid solutions and the quasi-binary, solid solu-
tions, lead telluride-tin telluride and lead telluride-lead selenide, have been investigated. Metal solution calorimetry has been applied to measurement of the heats of formation of intermetallic phases below room temperature. The behavior of solutes in lead-rich and tin-rich binary, ternary, and quaternary liquid solutions has been investigated by thermochemical measurements.

Investigations into the deformation of silver-rich, silver-magnesium and silver-cadmium solid solutions have been completed. In this work, the effects of short-range and long-range order on deformation behavior, the changes in electrical and mechanical properties, and the energies stored during deformation have all been of interest. An investigation of the effects of short-range order in copper-aluminum alloys is, it seems, the first systematic research relating measurements of short-range order by X-ray diffraction to mechanical behavior. In completion of work on the effects of radiation on electronic materials, the disordering of the ordered compound, Bi₂Te₃Se, caused by proton irradiation, has been studied.

**PROCESS METALLURGY**

Professor John F. Elliott and Professor Emeritus John Chipman have undertaken a joint study of the thermodynamic properties of austenite containing various alloying elements. The experimental methods include gas-metal equilibration and a new type of reversible EMF cell that has a carbide-bearing electrolyte. Dr. Shiro Ban-ya devoted his second year's stay at M.I.T. to this work and has now returned to Japan to continue his teaching there. Dr. Marc Onillon, who recently received his degree from the University of Bordeaux, is working with the carbide-bearing cell. Also working with Professor Elliott this year is Professor Hiroshi Sakao, from the University of Nagoya, Japan. He has undertaken the task of measuring the thermodynamic behavior of silicon in austenite from 1,100° to 1,400°C, using the EMF technique with a silicate electrolyte.

Professor Elliott has continued his study of the sulfides of the refractory metals; the work has been directed to measuring some of the electrical properties of these sulfides above 900°C, and to devising several new types of EMF cells for determining the thermodynamic properties of the sulfides.

In a program supervised by Professors Elliott and Merton C. Flemings, the influence of the process of solidification on the morphology and composition of oxysulfides in the iron-sulfur-oxygen system is under study. So far, the observations may be explained by a model of the process which calls for the particles of the oxysulfide phase to be isolated from each other by dendrites of iron.
Professor Elliott has started work on a small-scale, electroslag melting system and hopes to determine the temperature distribution in and near the consumable electrode. Work on dynamic analysis and simulation of metallurgical systems has been restricted to the completion of two Bachelor's theses, one on the development of a successful model of the continuous steelmaking system, using the spray technique developed by BISRA (British Iron and Steel Research Association) and the second on a small-scale model of a general computer system for the storage, retrieval and use of thermodynamic data on metals and inorganic compounds.

Professor Derek J. Fray, in a continuing study of the structure of phosphate melts, has found that up to 10 mol per cent of silica can be successfully added to the melts. In sodium phosphates, the results (using the chromatographic method developed by Meadowcroft and Richardson) indicate that silicon ions substitute for phosphate ions by taking part in the formation of the chains rather than contributing by attachment at the ends.

Under Professor Thomas B. King's direction, Barry H. Rosof has continued his work on the development of a theory of dynamical processes involving the application of Hamilton's principle. The method is more general than irreversible thermodynamics and has been successfully applied to a number of problems in which coupled processes are involved, such as the thermoelectric effect and second sound in liquid helium. Professor King has also started work on the kinetics of electrode reactions as they pertain to the electroslag remelting process. In the first instance, the elimination of sulphur from a liquid iron electrode and its removal from the electrolyte at an inert anode are being studied. The technique is that developed by Ghosh and King and involves an adaptation of the galvanostatic method used in low-temperature work.

SURFACE CHEMISTRY

Professor Philip L. de Bruyn and William Morris have made a theoretical study of the response of surfaces to environmental change. The continuum equations of balance for a Gibbsian surface have been developed. The study also presents a suitable tensor geometry of surfaces and shells of general form undergoing arbitrary deformation. The balance equations are shown to reduce to the known equilibrium equations of surface thermostatics and shell elasticity when all fluxes vanish. The second part of the problem considers the stability and slow motion of a fluid wetting a solid surface. Static hysteresis of the angle of three-phase contact is
considered as a consequence of roughness, chemical heterogeneity, and “dynamic pinning” of the junction line.

The adsorption of the potential determining ions, H\(^+\) and OH\(^-\), at the nickel hydroxide-solution and the nickel oxide-solution interfaces was studied by potentiometric titration methods. This study showed that morphological changes are introduced in the nickel hydroxide precipitate during the adsorption process when the pH of the solution is changed from acid to basic. It was also observed that the point of zero charge, which lies between pH 9 and 9.4, can thereby be shifted to pH 7.4.

CORROSION

Professor Herbert H. Uhlig, in a study of the initial oxidation kinetics of metals in the thin film region, has shown that gaseous pre-treatment of copper leads to surface faceting which, depending on the gas and crystal face, has a major effect on thin film oxidation behavior. Experiments to differentiate between the electrochemical theory of crack propagation in metals and an alternative theory, based on the reduction of surface energy by adsorbed ions, are being continued. The effect of galvanic coupling is being studied and measurements of the critical potential below which damage does not occur are being made. The work is at present mainly on stainless and carbon steels. Other work in the corrosion laboratory is on the mechanism of hydrogen cracking of steels, the mechanism of corrosion fatigue, and passivity in copper-nickel alloys.

CERAMICS

PROCESSES Professor Bernhardt J. Wuensch is continuing his work on grain boundary diffusion, studying the diffusion rate of thallium in KCl. The lattice diffusion rate in single crystal KCl has been determined and diffusion rates are now being studied in bicrystals of controlled orientation. A companion study is being initiated on diffusion transport in alkali halides subjected to stress.

Professor Donald R. Uhlmann's work on crystallization and melting kinetics in glasses has shown that, in germanium oxide glasses, growth rates depend on the atmosphere in which the crystallization is carried out. It has been found possible to produce germanium oxide glasses differing in water content and state of reduction by varying the atmosphere and temperature of melting. The effects of residual water and state of reduction on viscosity and growth rate are being determined. Work on the effect of high pressure on crystallization and melting kinetics has also continued, using silica, boric oxide, and albite as materials for study.
Professor Robert L. Coble's work on densification and grain growth in powder compacts has shown that densification during sintering of zinc oxide and subsequent pore growth after sintering are quantitatively consistent with models in which the kinetics are governed by transport in the lattice. It has been further shown that essentially all the mechanistic analyses of the initial stages of sintering based on initial shrinkage are probably in error. Professor Coble's new technique for measuring oxygen diffusion in alumina has yielded results which are more precise but which generally confirm earlier results of Kingery. The diffusivity is found to be dependent upon dislocation density within the crystals and independent of the impurity content.

Professors W. David Kingery and Cyril J. Mogab are studying the phenomenological theory of processes distributed in activation energy. An attempt is being made to interpret distributions of activation energies in terms of molecular models.

STRUCTURE-PROPERTY RELATIONSHIPS  Professor Wuensch, in his study of the crystal chemistry of glass-forming sulphides, has discovered an intermediate crystalline phase AsSbS$_3$ which bears no apparent relationship to the structure of the end members of the system Sb$_2$S$_3$ (which is a chain structure) and As$_2$S$_3$ (which is a layer structure). Professor Wuensch has further studied the relationship of valence electron concentration to the existence of over 200 phases in which bonding occurs through sp$^3$ hybridization. These are some of the important semiconductor materials. There are some exceptions to the rules which govern existence of these phases and it is suggested that the compositions assigned or the crystal structures determined are incorrect. In one example, the mineral colusite, which has been reported to have a sphalerite structure, it has been found that supposed single crystals consist of an intergrowth of tin-rich and tin-poor phases. The true composition of these phases is now being determined by microprobe analysis.

Professor Wuensch has completed a structure determination of PbAgAsS$_3$. The structure of the antimony analog is now being redetermined. Professor Wuensch is also studying the crystal chemistry of the manganese layer silicates. In one interesting case, the structure shows an interaction which seems to be repeated over several hundred angstrom units.

Professor Kingery is studying the solid solution behavior of impurities in high-purity, single-crystal alumina. Density changes calculated from proposed solubility mechanisms are compared with measured changes. Results indicate, for example, that titania goes into solution in the
alumina lattice by a substitutional method. Chromium ions substitute directly for aluminum ions in ruby. An electron-beam technique has been used to zone-refine alumina rods. Examination of impurities which have been left behind in the end sections indicate that carbon, magnesium and uranium are the only impurities for which the concentration is reduced by zone-refining. The other impurities merely undergo zone leveling.

Professor Coble has been studying dislocation velocities in calcium fluoride and has found that the velocity for screw components is higher than for edge components.

**Structural and Properties of Non-Crystalline Solids**

Professor Uhlmann has made measurements of viscous flow in glass-forming liquids such as salol and glycerine. For salol the log viscosity versus reciprocal temperature relations are straight lines over the viscosity range from $10^5$ poise to the glass transition region, while for glycerine some curvature is noticed at high viscosities. The implications of these results on various theories of the glass transition are being explored. Measurements of flow at high stresses on borosilicate glasses show no anomalous flow even for periods up to weeks in duration. In contrast, rubidium silicate glass has been found to show a significant decrease in viscosity with increasing stress at stress levels above $3 \times 10^4$ psi.

Professor Uhlmann has investigated the permanent densification which occurs in some glasses subjected to high pressure. There have also been studies of electrical conductivity and density of a series of simple silicate glasses in which partial substitution of one alkali ion for another is made. When combined with electron microscope observations, the measurements demonstrate that phase separation is not required for the occurrence for the so-called mixed alkali effect (a marked increase in resistance which accompanies partial substitution).

In Professor Uhlmann's work on splat quenching, a large number of materials have been obtained in the amorphous solid state. A seemingly amorphous form of ice has been obtained which crystallizes in the same temperature range as amorphous, vapor-deposited samples.

Professors Kingery and Mogab have studied annealing kinetics in non-crystalline silicon, germanium, and silicon carbide. The materials are obtained in a metastable, non-crystalline state by vapor quenching. All undergo an irreversible diminution of conductivity on annealing which has been attributed to the annihilation of acceptor levels near the edge of the valence band. The kinetics of the annealing process in non-crystalline silicon carbide have been studied and it has been found that the rate is logarithmic, consistent with thermally activated processes distributed in activation energy.
Professor Kingery has also obtained a metastable phase of barium titanate, using a flame-spray technique. The product shows amorphous X-ray and electron diffraction patterns. A transition to the crystalline phase begins at 490°C, with nucleation and growth of barium titanate particles. Professor Mogab has made electron scanning diffraction studies of vapor-quenched silicon films, in conjunction with Professor Moss. The major result of the work is an experimental confirmation that the films are truly non-crystalline. Transition to the crystalline state occurs at 620°C by a nucleation and growth mechanism.

POLYMERIC MATERIALS Professor Uhlmann is using a Bridgman anvil apparatus and a 200,000-psi gas apparatus to study the permanent changes in the properties of amorphous polymers produced by various combinations of high temperature and pressure. In polymethyl methacrylate a densification of 1.5% per cent has been achieved by treatment at the glass transition pressure corresponding to a given temperature. The kinetics of the annealing behavior of the densified polymers at atmospheric pressure and below the glass transition temperature are being investigated. The deformation of amorphous and crystalline polymers, with emphasis on the “cold flow” phenomenon, also is being studied.

ELECTRONIC MATERIALS
The research of this group continued to deal with the preparation, purification and characterization of semiconductors and superconductors. Professors Gatos and Witt have produced exciting results in studies of the incorporation and distribution of trace impurities in semiconductor single crystals. For the first time it has been demonstrated, theoretically and experimentally, that the main cause of impurity heterogeneities during solidification from the melt is thermal asymmetry at the solid-liquid interface. Experimental verification of the thermal asymmetry model was made possible by the development of a new method to determine the microscopic, instantaneous rate of solidification. A natural consequence of the work was to create conditions leading to homogeneous distribution of impurities in solids. A crystal puller has now been designed that allows complete control of the parameters affecting thermal asymmetry during solidification. What is believed to be the most homogeneous single crystal of a semiconductor ever prepared has been produced using this puller.

Professors Gatos and Witt have grown single-crystal beta silicon carbide epitaxially on silicon substrates using a mixture of silane, propane and hydrogen. The films exhibit some variation in thickness, attributed to unfavorable gas flow conditions.
High pressure studies, under Professor Gatos, are carried out at the M.I.T. Lincoln Laboratory and there has been further progress on phase relations and polymorphic transformations in the HgSe-HgS system. Better data are being obtained on the pressures at which various transformations occur in other electronic materials. Also at the Lincoln Laboratory, Professor Gatos, working with Dr. Thomas B. Reed, has developed a new technique for the growth of single crystals of high-temperature materials, employing the cold hearth technique of arc melting. Crystals are pulled in Czochralski fashion from the molten puddle. Niobium oxide has been grown in this manner and its electrical properties measured. It exhibits metallic conductivity at 300°K and is superconducting at about 1.4°K. Other work on superconductors has included the determination of critical currents as a function of magnetic field for 40 representative compositions of the titanium, niobium, vanadium ternary system. Critical currents as high as 4 x 10³ amperes per square centimeter at 80 kilogauss have been observed.

Work on compound semiconductor surfaces, under Professors Gatos and Witt, has yielded some interesting results. The surface conductance and photoconductance have been measured under close temperature control. Distinct surface states have been identified and quantitatively characterized. It is believed that these surface states are of paramount importance in understanding the real surfaces of semiconductors.

Professors Wulff and Rose have continued work on various aspects of superconductor materials. In studies of the current-carrying capacity of the most widely used Type II, Ti-Nb solid-solution superconductor, the influences of composition and processing variables on the structure and superconducting properties have now been definitely established. In particular, it has been shown that increasing the oxygen content increases the superconducting current, but at the expense of easy fabrication. However, minor additions of rare earths make it possible to process such brittle alloys in order to obtain optimal superconducting properties.

Professor Rose, in work on superconducting niobium-copper composites, has shown the existence of very strong proximity effects. The energy gap for superconductivity in niobium single crystals has also been determined, as a function of crystallographic orientation, over the entire K-space, by tunneling. It is believed that this is the first time this has been done for the transition metals, and only the second time that single-crystal tunneling has been successfully achieved in any superconductor.

MATERIALS PROCESSING

Professor Wulff, in a completely new study on surgical implant alloys,
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has been working with Dr. Jonathan Cohen from Harvard Medical School. In studies of three families of suitable surgical implant alloys, stainless steel, cobalt-chromium-molybdenum alloys and titanium-base alloys, it has been found that the bulk and surface mechanical properties of the alloys are as important as the corrosion properties. These studies have led to an alloy development and mechanical processing program which, in conjunction with tissue tolerance studies, should lead to less degradable implant alloys than are presently employed in surgery.

CASTING AND SOLIDIFICATION  Professor Flemings and his students have broadened their work from solidification, in which the primary activity still resides, to work on composite materials and the influence of thermal-mechanical treatments on structure and properties of wrought materials. Recent work on microsegregation and macrosegregation is now the basis of a large number of applied programs in this and other research groups. The work on segregation is continuing, with particular emphasis on behavior of inclusion-forming elements. The factor which is of major importance in determining segregation seems to be the direction of fluid flow with respect to solidification isotherms. Experiments agree qualitatively and quantitatively with the analytical results.

Studies of the growth of non-metallic inclusions have been made in the iron-silicon-oxygen and iron-sulphur-oxygen system. Apparatus which permits observation of dendritic growth and inclusion formation in melts during solidification has been constructed. The alloys presently employed are low-melting and the solidification process is viewed microscopically, using polarized light. In related work on ingot solidification, computer simulation of heat and fluid flow in solidification has suggested new ways in which to improve ingot homogeneity and refine ingot structure. These results are to be tested by experiment. Other solidification research under Professor Flemings' supervision includes study of the effects of extremely high rates of fluid flow on solidification (velocity gradients at the liquid-solid interface are as high as $10^5$ per second) and studies of levitation melting and splat cooling of various alloys. Coarsening (ripening) significantly alters solidification structures even at the rapid solidification rates encountered in splat cooling.

The newer work on thermal-mechanical processing is being carried out on high-strength aluminum alloys. It is a study of the combined influences of heat treatment and working on second-phase "inclusions" and the effect of these inclusions on fracture behavior and mechanical properties. Effects of major engineering importance are found, as expected from recent related studies of Professor Walter A. Backofen and
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Professor Frank A. McClintock of the Department of Mechanical Engineering. Work on composite materials is concerned primarily with new processing methods for producing such materials, for example, by the addition of particulate materials to molten metals.

MATERIALS JOINING Professor Clyde M. Adams has brought a five-year research program on heat flow in welding to a successful conclusion, with the generation of a manual from which predictions of thermal cycles as a function of welding parameters can be made for a wider variety of processes and conditions. Significant advances have also been made in the measurement and interpretation of residual stress distributions associated with hindered thermal contraction of arc welds. An important practical consequence has been the development of submerged arc techniques for welding heavy copper plate.

There has been a continuing study of high-intensity heat sources for fusion welding, the most important of which are the ruby laser and spark-arc percussive discharge. The laser is showing some promise as a means of fabricating dental structures, and percussive welding is particularly effective for the joining of very high conductivity materials such as silver and copper.

In brazing, at temperatures above 1,400°F, it has now been established that any liquid metal can be made to wet any solid surface, by using vacuum deposition as a pretreatment technique. This has opened the way for brazing such materials as graphite, ceramics and carbides. Solidification research has continued in the welding and ice research laboratories and theoretical and experimental efforts have been addressed to the elucidation of a basic relationship correlating dendritic growth structures with liquid-state mass transfer and liquid-solid interfacial energies.

DEFORMATION PROCESSING Professors Backofen and David L. Holt have continued their studies on the mechanisms of superplasticity, ductile fracture and texture formation. Of the many specific research findings, perhaps the most interesting development is in work which grew out of a freshman seminar. The Gorham Silver Company had a number of intricate and expensive but obsolete dies for conventional sheet-metal working operations. They were a little too soft to be used with modern materials if the intricate cutting was to be preserved but have now been successfully adapted for superplastic forming, using an alloy which is subsequently silverplated. This may be an historical first, since no other laboratories seem to have applied superplastic forming in an actual processing operation.
Professor Cyril Stanley Smith is continuing his work on the application of metallurgical methods to the study of early technology, with the help of a grant from the Sloan fund at M.I.T. A further grant from the National Endowment for the Humanities has just been received to assist in future work. The laboratory is achieving general recognition and has been invited to participate in three international conferences on the application of science to the study of artifacts and works of art. Precautions have had to be taken for the storage of many valuable artifacts during those periods when they are not actually under examination.

STAFF

The most notable change in the faculty this year was the retirement of Professor John Wulff. Although Professor Wulff is best known as a remarkable teacher, particularly of freshmen and sophomores, who was the first to hold the Class of 1922 Professorship and who won the principal awards for teaching of the two metallurgical societies, he also had an enviable record in research, which ranged from the fine structure of spectral lines through almost every aspect of the processing of metals. He pioneered the Sloan Metals Processing Laboratory and has done a great deal to infuse a feeling for the engineering aspects of metals processing in the Department. Fortunately, he will continue to teach on a part-time basis and is undertaking a new freshman subject on the chemistry of solid materials. Professor Derek J. Fray has resigned to accept a position with the Imperial Smelting Company in Avonmouth, Wales. Professor Fray's contributions to the teaching of thermodynamics and supervision of research in chemical metallurgy are much appreciated. Barry H. Rosof has been appointed to the faculty to replace Professor Fray, but his interests will be more in the direction of process analysis than thermodynamics. Assistant Professor John F. Breedis was promoted to Associate Professor. A long association with M.I.T. has been interrupted by the departure of Professor Clyde M. Adams Jr., who will be on leave of absence in the coming year at the University of Wisconsin (Milwaukee). Professor Adams will occupy the Pelton Chair at Wisconsin and will organize a metals processing group with the cooperation of local industry in the Milwaukee area. His keen mind will certainly be missed in the welding and joining area as well as generally throughout the Department. Dr. Stanley Weiss, Research Associate with Professor Adams for a number of years, will join him at Milwaukee.
Professor Morris Cohen was elected to membership in the National Academy of Sciences, bringing to three the number of members in the Department, the others being Professor Cyril Smith and Professor Emeritus John Chipman. Professor Cohen spent the first term on sabbatical at Cornell University and at a number of universities and industrial laboratories during the second term. While Professor Cohen was on leave at Cornell, Professor Herbert H. Johnson spent the year at M.I.T. He took over Professor Cohen’s teaching duties and contributed also to the research. His efforts were much appreciated by both students and faculty. Professor Emeritus Antoine M. Gaudin spent the spring term at the University of Alabama, advising a group in mineral extraction.

Professor Harry C. Gatos had a busy year acting as Associate Director of the Center for Materials Science and Engineering and as President of the Electrochemical Society. The Presidential address to the Society was followed by a musical evening with a quartet in which Professor Gatos played the flute.

Professor Cyril Stanley Smith was Visiting Fellow of St. Catherine’s College, Oxford University, during the Trinity Term and was also George Sarton lecturer of the History of Science Society and the American Association for the Advancement of Science.

Professor Robert E. Ogilvie took delivery, on behalf of the Center for Materials Science and Engineering, of a new scanning electron microscope, an instrument which is in great demand. With Professor Cecil E. Hall of Biology, he also organized an international conference on high energy electron microscopy in Japan. Professor Ogilvie is seeking to establish a center at M.I.T. for high-energy microscopy.

Professor John W. Cahn was the McDonald lecturer at the Canadian Metal Physics Conference.

Professor Nicholas J. Grant has been appointed Director of the Center for Materials Science and Engineering, succeeding Professor Robert A. Smith, who has been appointed Principal of the Heriot-Watt University in Edinburgh, Scotland.

Among the research associates there has been some turnover. Dr. Giessen has assumed a faculty appointment in the chemistry department at Northeastern University. Dr. Thomas H. Courtney will join the faculty at the University of Texas and Dr. Joseph T. Blucher has become Director of Research for Simonds Saw and Steel. Dr. Shiro Ban-ya completed two years as Research Associate with the chemical metallurgy group and accomplished a remarkable amount of work on the measurement of sulphur activity in metallic solutions of varying complexity. Dr. Hiroshi
Sakao from Nagoya University has also joined the chemical metallurgy group as Visiting Scientist.

Dr. Masao Santa, from Mitsubishi Metal Mining Company, spent the year with the electronic materials group and Dr. Jerzy S. Sochanski, on a year's government exchange program, joined the same group from the Polish Academy of Sciences. Dr. Thomas Thomsen, from the Technische Hochschule Darmstadt, joined Professor Backofen's group, and Trebor P. Jones, from the National Standards Laboratory in Australia, spent the year with the ceramics group as Visiting Scientist. Dr. Hannes Böhni, from the Swiss Federal Institute of Technology, was a postdoctoral fellow with Professor Uhlig. Dr. Fedor A. Kuznetsov, Head of the Film Semiconductor Laboratory of the Academy of Sciences, Novosibirsk, spent a year with the electronics group and Dr. Frank S. Gardner continued his association with Professor Cohen as Research Affiliate. All these associations have been valuable but the Department will particularly miss Dr. Courtney's contributions to the teaching of the graduate subject for naval officers.

The Colloquium was arranged by Professor Rose and consisted of contributions from our own faculty to bring us up-to-date on their main research themes. The Robert S. Williams Lectures, in a departure from tradition, were given by Dr. Herbert H. Hollomon, a distinguished alumnus, and President-elect of the University of Oklahoma. Dr. Hollomon chose as his topic, "Technology and Society." His first lecture was followed by an evening meeting at which a panel consisting of the Provost, Dr. Jerome B. Wiesner, the Dean of Engineering, Dr. Gordon S. Brown, Dean Harvey Brooks from Harvard, and Dr. Eugene B. Skolnikoff of the Department of Economics participated in an open discussion. The talks and discussion were very well received and WGBH has since re-broadcast Dr. Hollomon's remarks.

A notable addition to the facilities of the Department was the completion of the faculty/student lounge opposite departmental headquarters. It is beautifully furnished and we owe thanks to the Institute, industrial companies and the alumni for their aid in funding. Professor Emeritus Chipman, for whom the room is named The John Chipman Room, was honored at a brief ceremony during which he was presented with a key to the lounge.

Three employees with long service records, William Martin, Roland Seger, and Rupert Whittemore, retired this year. We will have to adapt to doing without their individual skills.

THOMAS B. KING
The Annual Report of the Department of Naval Architecture and Marine Engineering for 1966-67 established the need for broadening the scope of the Department in order to encompass ocean transportation, naval engineering, and ocean engineering. The educational program of the Department, in order to be responsive to these broad needs, must develop in the student the necessary background knowledge in the engineering sciences as well as the engineering attitudes to apply this background in finding meaningful solutions to practical problems; that is, to view engineering tasks within the framework of the respective systems and objectives, to design creatively, and to analyze thoroughly.

The goal of the educational program of the Department is to stress principles of engineering sciences, integration process of design, and concept formulation for systems as the link to real world problems; and to develop the capability to identify and define problems in addition to the capability to solve them.

The Department is essentially a graduate department with about 140 graduate students and about 25 undergraduates. In recent years, the number of undergraduates has been rather constant, while the graduate enrollment over the last six years has shown a steady increase. The increase in civilian enrollment over the last ten years is especially encouraging (see Table I).

During the last year, the Department of Naval Architecture and Marine Engineering has begun the systematic implementation of its plan for broadening its operation. The resulting program is discussed in this report.

UNDERGRADUATE PROGRAM

The Department undertook an especially challenging task in 1967-68 — to introduce a new subject, available to all freshmen without prerequisite, that hopefully would excite their interests in engineering as a profession. The subject was developed by Professor Philip Mandel and taught by him for the first time in the 1968 spring term to a very dedicated group of 16 freshmen. The subject content included the basic principles governing vehicle support forces, drag forces, and the production of thrust. These principles were then applied to show the advantages and disadvantages in a technical sense of airplanes, hydrofoils, air cushion vehicles, surface ships, planing craft and submarines, each in relation to the other. It was then possible to explain the position of these vehicles in the current
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<tr>
<td>Total Graduate Enrollment</td>
<td>103</td>
<td>96</td>
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<td>90</td>
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<td>83</td>
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<td>124</td>
<td>116</td>
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<td>120</td>
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<tr>
<td>Total Civilian Enrollment</td>
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economic scene and to make forecasts of their position in the future. It is planned to develop this subject further and to offer it again in 1968-69.

The basic subject of the Department, Principles of Naval Architecture, 13.00, has been revised extensively by Professors Justin E. Kerwin and John N. Newman in order to provide a more extensive and coherent introduction to ship hydrodynamics. The four classical topics of resistance, propulsion, seakeeping and maneuverability are presented as applications of the fluid mechanics of viscous flows, water waves, and lifting surface effects; the subject is organized on the basis of the last three topics. This new format emphasizes the principles that are involved and the similarities that exist between the four classical subdivisions of naval architecture. The number of laboratory sessions in this subject has been doubled by making these sessions shorter and less formal; this has allowed exposure to a broad spectrum of phenomena, including basic flow phenomena which can be readily observed in the Towing Tank and Water Tunnel. For use in classroom demonstrations in this subject as well as in other graduate and undergraduate subjects on ship hydrodynamics, a portable circulating water channel has been constructed out of transparent plastic; this facility can be brought into the classroom to facilitate direct observations of ship waves and wave effects.

The interest in the freshmen seminar on Sailing Yacht Research continues.

William G. Zink, now enrolled in the five-year Course in Shipping and Shipbuilding Management, received the American Bureau of Shipping Prize awarded for the highest scholarship in the third and fourth year of the Course in Naval Architecture and Marine Engineering.

GRADUATE PROGRAM

GENERAL

The graduate enrollment climbed sharply to 140 in 1967-68, compared to 120 in 1966-67. This increase in enrollment is partially due to the inauguration of the Ocean Engineering Graduate Program but is also due to increases in the established segments of the Department’s graduate program. No further increases in enrollment are expected in 1968-69 although the number of qualified applicants rose sharply.

The Department’s doctoral program, which entered a new period of sustained interest in 1964, is showing increasing strength. There are currently 14 graduate students in the Department who have passed the doctoral qualifying examinations and who are working on their doctoral theses. Table II shows the number of doctoral degrees awarded annually for the past decade by the Department.
SCHOOL OF ENGINEERING

Table II  Number of Ph.D. and Sc.D. Degrees Awarded by the Department of Naval Architecture and Marine Engineering, 1957-1968

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Number of Doctoral Degrees Awarded</th>
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<td>1966-67</td>
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<td>1967-68</td>
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NAVAL ARCHITECTURE AND MARINE ENGINEERING

Expansion of the subject offering is illustrated by the development of new graduate subjects during the past year.

During the fall term, Professor Newman offered Free Surface Hydrodynamics, covering the theory of water waves with applications to ship hydrodynamics, including wave-resistance theory and ship motions in waves. These topics are being applied to an increasing extent in modern naval architecture and ocean engineering.

Signal Measurement and Handling was offered by Professor Jerome H. Milgram. Although naval architects, marine engineers and ocean engineers frequently must make measurements, it has been found that many students in these fields lack a knowledge of the mathematical fundamentals involved. The new subject was developed to provide a knowledge of these fundamentals. In order that the subject be of value to a wide variety of students, the problems of individual transducers were not covered. Instead, the emphasis was placed on the handling of an electrical signal with regard to how to obtain the desired information from it and how to minimize and evaluate errors in signals.

The new subject, Modern Ship Production Techniques, was initiated during the fall term and attended by nine students. This subject, under the direction of Professor Ernst G. Frankel, developed analytical methods for the design and operation of modern ship production facilities. It utilizes a background of operations research, systems engineering, and control engineering analyses for the development of methodology for the design of more productive and effective ship production facilities, their organization, management and labor utilization. Problems of effective use of numerical control techniques in ship production flow, material flow and information flow were analyzed and various models developed and
discussed. The subject also covered modern production techniques, including dimensional control and alignment of large prefabricated sections. Similarly, problems of ship erection and launch, as well as pre-installation of outfitting, were covered in these lectures.

A new subject, Acoustics of Submerged Structures, 13.97, was added to the program on ship acoustics. This subject was conducted by Dr. Miguel C. Junger, a senior lecturer in the Department and a well-known authority in the field. Notes prepared for this subject are forming a basis for a definitive text in this field.

In addition to these new subjects offered during the 1967-68 academic year, preparations were started by Professor Alfred A. H. Keil for a new subject, Ship Structural Dynamics. Other new subjects specifically developed for ocean engineering will be described there.

Five students of the Department participated in the interdepartmental systems engineering subject given by the School of Engineering each spring under the general guidance of Assistant Dean William W. Seifert. This year's topic concerned an over-all plan for the future of the Boston airport and seaport extending over the time period 1968 to 1990. Project Bosporus, the code name of the resulting program, was the work of 38 students, primarily graduate students. Professor Frankel presented a series of lectures on ocean transportation and port development and guided the student teams concerned with the development of the future seaport. The results of this project were presented to a wide audience at Kresge Auditorium and will be published in report form later this year. A number of original and far-reaching ideas and engineering solutions for transportation problems of the future — including considerations of management, labor, legal and financial problems — were analyzed and developed.

XIII-A CURRICULUM

The basic Naval Construction and Engineering curriculum remained the same with minor modifications to take advantage of new subject offerings. This curriculum continues to emphasize the broad professional degree of Naval Engineer with specialization in hull design, marine propulsion or electrical-electronics engineering as recognized by the appropriate degree of Master of Science. This year, for the first time, a limited number of officers have begun to specialize in ocean engineering and nuclear engineering. These new areas of specialization will be reflected in the degree list for the class to be graduated in 1969.

The latest graduating class of 28 officers is one of the largest in recent years. It is expected that the total strength will remain at about 80 students. The graduating class was awarded 26 professional Naval Engineer
degrees and designated degrees of Master of Science as follows: nine in naval architecture and marine engineering, 15 in mechanical engineering and six in electrical engineering.

Computer applications continue to be stressed as important tools of the ship design process. This was reflected by several thesis topics on ship optimization together with continued high use of the computer in other thesis areas and design projects.

In Conceptual Design of Naval Ships, 13.46T, under Professor Robert E. Stark, assisted by Professor Sherman C. Reed, efforts were continued to give the students exercise in group solution to design projects. The projects were organized to emphasize concept formulation by requiring that the students first determine what characteristics will produce the best type of ship for the job on hand before proceeding to the task of designing the best ship to meet these characteristics.

Three broad projects were studied, with competing teams performing the concept exploration as well as the concept development phase.

One group of teams explored various methods of providing support for deep ocean salvage during high sea states. A catamaran type ship was shown to possess superior characteristics and competitive designs of such a ship were developed.

A second group of teams explored types of support ships for the proposed National Data Buoy System being investigated by the Coast Guard. For this mission, the mobile, column-stabilized platform was selected as an effective ship type and further developed.

The third group investigated methods of providing gunfire support for an amphibious assault operation. The concept selected for further development by competing teams was a combination of gun and rocket ships together with sea-based support ships for rocket-launching helicopters. The results of recent naval analyses in the area of gunfire support provided useful background and gave the problem a realistic flavor.

Lieutenant Samuel J. Gordon, USN, and Lieutenant Peter T. Tarpgaard Jr., USN, received the Graduate Paper Honor Prize of The Society of Naval Architects and Marine Engineers at the 75th Annual Meeting, November 15-18, 1967, for their paper, "Utilization of Propeller Shrouds as Steering Devices."

The Brand Award, given annually by the Society of Naval Engineers to the member of the graduating class in Course XIII-A with the highest academic standing was received by Lieutenant David L. Greene, USN.

OCEAN ENGINEERING

Ocean engineering integrates many existing engineering and scientific disciplines and applies them to the ocean environment. It consists of engi-
neering for the efficient conduct of modern ocean sciences, the exploration of ocean resources, and the development of engineering capabilities, engineering products, and undersea technology required to utilize these resources.

Eleven graduate students enrolled in September, 1967, in the new Ocean Engineering Graduate Program approved by the M.I.T. Faculty earlier in 1967. These 11 students represented seven different colleges, seven different fields of undergraduate training and received financial support for 1967-68 from seven different sources. For 1968-69 there were 22 applicants for admission to the Ocean Engineering Graduate Program, 14 of whom were offered admission. These 14 represent 12 different undergraduate colleges and nine different fields of undergraduate study.

New subjects specifically oriented toward ocean engineering which were offered for the first time at M.I.T. in 1967-68 are listed below. They were the result of a cooperative effort of the faculty of the Department of Naval Architecture and Marine Engineering, Professor Norman J. Padelford of the Department of Political Science, and Professor Frederick J. McGarry of the Department of Civil Engineering.

Ocean Engineering Structures, 13.17, taught by Professor John H. Evans, gives a broad introduction to structures designed to operate in the ocean environment, including anticipated loads and resulting response.

Politics, Law and the Oceanic Realm, 13.92T, offered by Professor Padelford, gives an overview of the legal and political problems associated with greater utilization of the ocean resources.

Motion Control of Ocean Vehicles, 13.98, given by Professor Martin A. Abkowitz, analyzes the hydrodynamic forces acting on oceangoing vehicles, including small submersibles and towed bodies, and considers the various means for motion control.

Materials for Ocean Engineering, 1.48, given by Professor McGarry, bridges from materials sciences to the multitude of special materials needed for ocean engineering application.

The development of these subjects was supported by the Sea Grant Office of the National Science Foundation under a Sea Grant Project for Curriculum Development for Ocean Engineering.

The Department participated also in the Joint Program in Oceanography and Ocean Engineering carried out by M.I.T. and the Woods Hole Oceanographic Institution (W.H.O.I.) in the summer of 1968 at Woods Hole. About nine students from this Department registered for the program, for which they will receive M.I.T. credit, and Professors Kerwin and Newman of this Department will help in the instruction. Professors Keil and Mandel were members of the Admissions Committee.
Research in the seakeeping performance of ships was carried out under the continuing support of the Maritime Administration. The efforts under this program were concentrated in two areas: (1) the development of a consolidated computer program for use in ship design from seakeeping considerations, and (2) investigations into bow "slamming" response of ships in a seaway.

All the individual computer programs developed during recent years for predicting motion response, added drag, bending moment loads and other factors under our seakeeping research has been consolidated into a master program, with simple input and output procedures, so that ship designers can readily obtain predictions of performance of a given design in the various sea states expected along the route. This is for the purpose of comparing alternate designs in meeting mission requirements as well as for evaluating the operational aspects of a given design. The general program format is such that subroutines are in "module" form so that specific subroutines need only be replaced or updated as better theory and computational techniques for evaluating specific responses are developed. The goal of this research project is to provide very useful information conveniently in the design process with minimum requirements on the part of the users.

It is necessary to determine the degree of "slamming" expected in a seaway in order to estimate whether a skipper will slow down his ship to avoid damage. Research was initiated this year at M.I.T. to develop a capability to calculate the frequency and severity of "slamming" in a given seaway. A search of the literature has been carried out, and model tests in which keel pressure in a seaway is measured are under way. It is hoped to develop a method of determining when a slam occurs that will improve on the present crude criteria now assumed.

Model tests of a push-towed segmented barge train have been carried out in which motions as well as hinge and link loadings were measured. The results are compared to the values calculated by the theory mentioned in last year's report.

Under the Deep Submergence Rescue Vehicle (DSRV) Research Program, a one-twelfth-scale model of the DSRV hull was built and tested in the Ship Model Towing Tank and the Wright Brothers Wind Tunnel. A multicomponent velocity sensor, critical to the vehicle's sophisticated control system, is being developed and evaluated. Also, inflow velocities into the various ducts of the control thrusters are being measured for various angles of attack to help determine propeller thrust action. Critical
to the “feed forward” nature of the control and display system is the formulation of an accurate hydrodynamic model of the vehicle in all its modes of operation. Under this project forces and moments at all angles of attack (in the highly non-linear range) are being measured, and appropriate schemes of mathematical modeling of such information are being investigated.

Our unique facilities for conducting tests in long-time samples of purely random irregular seas of any specified spectral distribution have been used in a research program sponsored by the Navy to determine the maximum bending moment loads on destroyer hulls in extremely severe sea states. Comparisons between maximum loadings on a destroyer with and without large bow sonar domes are made. Extreme loadings are involved in the “survivability” aspects of ship design.

An attempt is being made to extend the step response method for determining hydrodynamic coefficients to include the measurements of coupling coefficients.

Fundamental aspects of ship waves are being investigated in a new contract under sponsorship of the Office of Naval Research. A non-linear analysis has been made of the mechanisms for energy exchange among different components of the wave system generated by a ship, and it has been found that significant interactions can occur along the outer boundaries of the classical Kelvin wave system. Under the same contract a Panel on Non-Linear and Viscous Effects in Wave-Resistance Theory is being organized to be held in conjunction with the Seventh Symposium on Naval Hydrodynamics to be held in Rome in August, 1968.

PROPELLER DESIGN

The characteristics of foils operating in water have been the subject of research in this Department for a number of years. A computer design method has been developed for moderately loaded marine propellers. This work is being extended to include heavily loaded propellers. With this object in mind a project has been completed to predict contraction of the propeller wake using ring vortex theory. Work has also been done on the prediction of tip vortex cavitation and the motion of the tip vortex downstream, which has a major effect on the pressure field both in the wake and at the tip of the propeller. At present, work is in progress on determining the loading at the tip of a propeller or a rudder, taking account of tip vortex rollup. This work will be included in the propeller design method.

Improvements have been made in the theoretical prediction of wall interference effects in the Water Tunnel and the flow around extremely
large propeller hubs. Water Tunnel tests are planned for the coming year to assess the results of this work. Theoretical work has been started on the design and testing of surface-piercing propellers.

A major effort is being made in the study of vibratory forces due to the interaction between the rotating propeller, non-uniform wake and the ship hull. Tests have been conducted with four-, five-, and six-bladed propellers of various blade widths and sections with various skews up to 100° and with various longitudinal propeller and rudder clearances. With an ingenious set-up developed by Professor Frank M. Lewis it is possible to measure both the total force acting on the hull and the force acting on the hull surface alone. Contrary to existing opinion, it has been found that except for the five-bladed propellers the surface force is larger than that transmitted through the shaft.

A major test program has been initiated to study the unsteady forces and moments on a rotating propeller with uneven inflow, in the Water Tunnel. Design for the instrumentation for this project is nearing completion.

**SHIP ACOUSTICS**

The investigation of stream reducer valve noise was successfully completed, and recommendations were submitted for improvements in these valves. The work on turbulent boundary layer noise was conducted throughout the year. Wall pressure statistics, panel response and acoustic radiation measurements were carried out. An investigation of the effect of surface roughness was commenced. A new project for the investigation of propeller singing was started. This project is operated jointly by the Acoustics and Vibration Laboratory and the Water Tunnel.

**SHIP STRUCTURES**

Work in the structures area has continued with further significant progress in computer-aided design. Foremost was the development of a completely restructured midship section structural design logic leading to a new benchmark design program sponsored by U.S. Steel Company. The essence of the program is its modularity. It derives from ten years of work toward rational design of ship structures and experience with other previous evolutionary design programs. Program capability now includes provisions for combination of up to five steels in any combination of framing systems with all likely types of mid-section geometry. It may easily be tuned to whatever code or design criteria may be desired, and methods of structural analysis within it may be readily exchanged. Requests for the program have been received from several industrial firms and branches of government.
Continuing recent investigations into the use of exotic steel in ship construction have been expanded from studies of optimum use as to choice and location, to an investigation of whether greater benefits would accrue from efforts to reduce steel price differentials or the fabrication differentials.

The relationship of structural design to over-all vehicle design through hull steel weight has also been studied with data supplied by the Navy, and improved means of weight estimation by way of the ship characteristics has been found. While the method has an entirely rational basis and shows promise, additional verification with a greater diversity of ships is now being attempted.

SHIP DESIGN AND SHIP SYSTEMS

The use of formal search techniques in ship optimization problems, first introduced to the profession as a result of work in this Department in 1965-66, has been widely adopted in government and industry and has been the subject of further thesis research in the Department. The particular search technique most thoroughly studied by this Department is routinely used by the Naval Ship Engineering Center in its conceptual design work.

The Department made a significant contribution to the development of a system concept for a hydrographic survey and charting system. The development of this system was supported by the U.S. Naval Oceanographic Office at M.I.T.'s Experimental Astronomy Laboratory, with participation by this Department. The parametric studies undertaken by this Department for the sounding vehicles needed for this system formed a major part of the final report on this project.

Research has continued on the mobile column-stabilized ship as a new ship form. This effort was initiated by three graduate students in a three-term effort starting at the beginning of the 1967 summer term. A considerable amount of information already developed elsewhere was gathered. Two theses relating to the resistance of the form and its structural design were accomplished by two of the students during the fall and spring terms. In cooperation with the U.S. Coast Guard the three students then participated in a preliminary design involving the use of this hull form for a recovery and servicing ship for a projected national data buoy system. Results of the three-term efforts indicate that there is some merit in a three-term approach to exploring new concepts in ocean vehicles and that there is a large amount of research remaining to be done on the mobile column-stabilized platform before it can be used successfully as an ocean vehicle.
A very strong interest on the part of one of the graduate students within this Department has resulted in initiation of research into ferro-cement as a ship structural material. Initial results developed by this student as a Department of Civil Engineering special project, indicate that the material can develop greater total tensile strength than its components. In a special project under the joint auspices of this Department and the Boston Naval Shipyard, several graduate students will engineer and construct a workboat out of the material during the coming summer term.

A unique thesis project in the area of ship systems was begun in 1968. The thesis accepts the following two facts as a challenge: (1) The current New England fishing fleet is apparently able to produce a living for its owners but does not provide sufficient income for fleet modernization without which the fleet will ultimately wither and die, and (2) a fishing boat can be an attractive naval auxiliary in wartime as a mine sweeper.

The thesis will examine the technical, economic, political, and human aspects of the problem with the ultimate objective of developing a vehicle design and subsidy system that will prove attractive to both government and industry.

OCEAN TRANSPORTATION

Research in the areas of ocean transportation and military sea lift were carried out and resulted in the construction of programs for the development of cargo loading sequences for unitized cargo ships as well as a program for the mobilization of ship capacity for sea lift requirements. Additional studies were performed on shipbuilding productivity and the effectiveness of government assistance to shipbuilding and ship operation.

The recently created position of Special Assistant for Strategic Mobility to the Joint Chiefs of Staff has led to the beginning of a unified mobility planning activity in the Department of Defense. Among the activities sponsored at M.I.T. during the past year has been an advisory study leading to definition of a program for research into issues affecting strategic mobility posture in the period 1980-2000.

This agency has also sponsored research in the Department principally on the properties of the interface between ocean transportation and air or land transportation. The throughput capacity of interface facilities is frequently critical to the response properties of long logistical supply lines. Understanding their behavior is necessary for planning the design and operation of such facilities for the future. During the planning reference interval, ship and vehicle technology will advance, thereby necessitating solution of new operating problems that derive from coupled systems of vehicles, transfer, and storage equipment. To the extent pos-
sible, these studies are carried out using performance properties of con-
tceptual systems with frequent reference to equipment presently available.

The Department of Transportation is supporting work of general ap-
plication to transportation systems through its Office of High Speed
Ground Transportation. This work deals with scheduling departures of
transportation vehicles such as ships, in response to a time-varying but
cyclical market for transportation services to satisfy a criterion that is
non-linear in its measure of cost of service performed. Operating over
well-defined routes, the market is serviced using vehicles of various
sizes, thereby providing measures of the fleet ownership and operating
costs and including some effects of market response to available service.

In various forms this problem is pervasive in all transportation. It
deals with selection and route assignment of aircraft; for example, the
research is jointly performed by the Department of Naval Architecture
and Marine Engineering and the Department of Aeronautics and Astro-


SHIP PRODUCTION

An effort was made by the Department to attract research in the area
of ship production, which is of increasing interest to a large number of
graduate students. The first such project consists of an extensive ex-
perimental and analytical examination of various methods for side
launching large ships.

LABORATORIES

SHIP MODEL TOWING TANK

Tank facilities continued to be improved partly through Ford Founda-
tion assistance and partly through maintenance funds. The six-channel
solid-state electronic recorder, recently acquired, saw continuous use in
a variety of tests carried out during the year. The new water filter and
water temperature control system effectively maintained the quality of
the Tank water to suitable test standards. A new heave rod riding on
"frictionless" air bearings was designed, built, and put into operation. Al-
so a new and novel drag dynamometer was built to include an accurate
and convenient capability for measuring added drag in waves. A new
solid-state sonic wave height probe has been purchased, and the old
sonic probe was overhauled. Also several resistance-type wave probes
were fabricated.

A prototype air bearing for the towing carriage was designed, built
and tested. Plans are to construct three more such bearings to support
the towing carriage on a cushion of air in order to keep carriage vibrations to a minimum. With unique capability of generating long time samples of purely random irregular seas (as mentioned in last year's report) and the recent adoption of standard sea spectra by the International Towing Tank Conference, a reasonable library of sea state spectra was generated onto magnetic tape. These tape programs control the wave maker in the Tank. The Tank aided in the purchase of some additional equipment for the hybrid (analog-digital) computer facility of the Department of Mechanical Engineering. This equipment has given the computer the additional capability of analog-to-digital conversion, a capability that is needed and readily used in digitizing model test data and performing analysis and data reduction.

Eleven theses, demonstrations for subject 13.00 and model tests for the Undergraduate Seminar, involved the use of the Ship Model Towing Tank. In addition, many research projects under M.I.T. and D.S.R. sponsorship as well as several commercial tests were conducted. Model tests at the Tank represented the areas indicated below:

1. Articulated ships in waves
2. Series of catamaran hull shapes
3. Planing landing craft
4. Propeller-induced hull vibrations
5. Deep Submergence Rescue Vehicle
6. Calibration of oceanographic equipment
7. Sailing yacht forces
8. Seakeeping response of the LHA (Landing Helicopter Assault) ship
9. Step response tests for determining coupling coefficients
10. Investigation of oil drift in waves
11. Forces on a surface breakwater
12. Buoy with self-power generation from waves
13. Drag forces on a sea platform
14. Forces on buoys in a deep-sea array
15. Maximum loadings on destroyers in extreme seas
16. Slamming pressures and response in a seaway

An engineer and a laboratory assistant were added to the Towing Tank staff, and the Tank Technician continues at full time with the Tank Manager, Theodore Loukakis, at 40 per cent time. Professor Abkowitz, Director of the Towing Tank, represented M.I.T. at the American Towing Tank Conference in Ottawa in June, 1968, in the capacity of Chairman of the Committee on Seakeeping. Mr. Loukakis also represented M.I.T. as a member of the Committee on Instrumentation, Data
Processing and Analysis. Professor Abkowitz is also a member of the Seakeeping Committee of the International Towing Tank Conference.

ACOUSTICS AND VIBRATION LABORATORY

During the year the low-noise, low-turbulence wind tunnel for flow noise research was improved substantially. An integrated control station was added. Sound absorbing wedges were installed facing the upstream inlet; and new sand-loaded, double-walled internal ducting was installed. These modifications have substantially improved our capacity to carry out boundary layer noise research.

Further support for laboratory instrumentation was provided by the Alfred P. Sloan Foundation. A precision Betz micromanometer, two high-gain preamplifiers, and two miniature microphones and associated cathode followers were acquired for use in flow-noise studies. The Laboratory conducted support of the academic program this year. One Master’s thesis was completed and three doctoral theses are under way. Laboratory demonstrations were carried out supporting subjects 13.92, 13.72 and 2.065.

WATER TUNNEL

This Tunnel, which was built in 1939 to test the mean thrust and torque of propellers, has been remodeled with support from the Alfred P. Sloan Foundation and a National Science Foundation (NSF) Grant to obtain more flexibility in the type of test possible. It was put back in operation in September, 1967, and has since been used heavily for research projects and demonstrations.

The new rectangular test section with transparent walls has allowed visual observations of cavity flow around foils, tip vortex cavitation and ventilation on rudder and propeller models, and the vibration of a commercial speed-measuring sensor due to the Karman vortex street. A project is under way to study the flow around a large hub propeller with hydrogen bubbles and stroboscopic photography. Improved and expanded electronic instrumentation has provided excellent results in dynamic measurements on supercavitating oscillating hydrofoils.

Instrumentation is being built to measure the forces and moments on a series of flapped rudders in a propeller wake. It is expected that the five-component dynamometer designed for this project will be extremely useful for testing hydrofoils and submerged bodies in the future.

The electronic instrumentation installed for the measurement of propeller characteristics has proven extremely accurate, simple to use, and reliable. Instrumentation for the measurement of unsteady forces on
propellers as well as tests on semisubmerged propellers is planned for
the coming year.

SHIP STRUCTURES LABORATORY
Plans for reactivating the Ship Structures Laboratory in its new location
in Building 5 are now being pursued actively with the full-time assis-
tance of three naval officer graduate students during the summer. New
emphasis is on dynamic structural response; additional faculty members,
arriving for the fall term, are already engaged in this field.

FACILITIES
The three Course XIII-A project rooms and the departmental student-
faculty lounge were rearranged to accommodate the XIII-A students in a
smaller area. The vacated space was remodeled to provide eight offices
suitable for faculty, plus additional office space for secretaries and re-
search assistants.

The offices in the vicinity of the departmental reading rooms were re-
modeled to change four inadequate offices into seven good offices.

The Headquarters offices plus adjacent faculty space were made more
suitable for their purposes.

All these changes were possible only because of the generous support
by Dean Gordon S. Brown and the administration and extremely coop-
ervative action by the Planning Office.

FACULTY
Associate Professor Frankel and Associate Professor Kerwin were pro-
moted to Professor.

Dr. Newman, formerly with the Navy’s David Taylor Model Basin,
joined the Department’s faculty as Associate Professor.

Dr. Jerome H. Milgram joined the faculty of the Department as As-
sistant Professor and a Ford Postdoctoral Fellow.

Dr. E. Farnsworth Bisbee, formerly Associate Professor in the De-
partment of Civil Engineering, joined the Department of Naval Architec-
ture and Marine Engineering as a Research Associate.

Assistant Professor Neal A. Brown resigned to accept employment in
industry.

Professor John H. Evans spent the spring term on sabbatical leave.

The Department was privileged to have four well-known experts as
part-time lecturers: Dr. Manley St. Denis, on naval systems, Dr. Miguel
C. Junger, on acoustics of submerged structures, Dr. Bernard W. Rom-
berg, on application of computer systems, and Leonard R. Doyon on
reliability analysis.
The cooperation of Professor Padelford and Professor McGarry in the development of the Ocean Engineering Graduate Program is gratefully acknowledged. Professor Padelford continues to participate actively in this Program, and his appointment as Professor in the Department of Political Science has been changed to a joint appointment with that Department and our Department.

The areas of interest of the individual faculty members and the lecturers are listed in Table III.

SEMINAR AND SYMPOSIA

Two one-week intensive Summer Programs were directed by Professor Frankel during July, 1967.

The first, entitled “Ocean Transportation,” was attended by 38 registrants, who listened to lectures on ocean transportation analysis, transportation economics, transportation systems management, operations research modeling of ship routing and loading, and to discussions on management information systems, unitized cargo handling and intermodal transportation problems. The Program was based on a set of lecture notes, and four outside speakers assisted Professor Frankel.

A one-week intensive Program on Modern Ship Production was given by Professor Frankel with the assistance of three outside speakers; the Program covered topics such as modern ship production techniques, shipyard layout analysis, publication process analysis and control, shipyard management information systems design, ship welding and distortion, ship erection and launch, and shipyard management and labor problems. This Program was attended by 68 registrants and about 30 guests.

These two Programs received wide support and interest, and the Department contemplates continuing similar programs of meaningful and topical content during future years.

The Department organized a special lecture series on ship welding and welding distortion under Dr. Koichi Masubuchi of the Battelle Memorial Institute during the spring of 1968. The lecture series consisted of nine lecture hours and was attended by an average of about 70 people representing roughly equal numbers of industry personnel and graduate students.

A special lecture series on Transportation Systems Analysis was given by Franz Frisch of the Research Analysis Corporation. This five-week series was attended by students participating in various transportation engineering processes in the Departments of Naval Architecture and Marine Engineering, Civil Engineering, and Mechanical Engineering.
<table>
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<tr>
<th>Faculty</th>
<th>Lecturers</th>
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<tr>
<td>Akkowitz</td>
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<td>Evans</td>
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<td>Keil</td>
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<td>Leahey</td>
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<td>Lewis</td>
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<tr>
<td>Mandel</td>
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<td>Stark</td>
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<td>Frankel</td>
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<td>Kerwin</td>
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<td>Newman</td>
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<td>Padelford</td>
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<td>Powell</td>
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<td>Reed</td>
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<td>Milgram</td>
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<td>Junger</td>
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<td>Doyon</td>
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<td>Romberg</td>
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<td>St. Denis</td>
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<tr>
<th>Areas of Faculty Interest</th>
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<tr>
<td>Ship hydrodynamics</td>
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<td>Propulsion hydrodynamics</td>
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<tr>
<td>Ship structural mechanics</td>
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<tr>
<td>Ship propulsion mechanics</td>
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<tr>
<td>Hydroacoustics</td>
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<tr>
<td>Materials science</td>
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<tr>
<td>Principles of management</td>
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<tr>
<td>System analysis</td>
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<tr>
<td>Computer applications</td>
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<tr>
<td>Ship structures</td>
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<td>Vehicle design</td>
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<td>Power systems</td>
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<td>Production engineering</td>
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<td>Ocean transportation</td>
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<td>Naval systems</td>
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<tr>
<td>Ocean engineering systems</td>
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<tr>
<td>Public law and use of oceans</td>
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* Area of interest
** Area of major interest
The weekly seminars of the Department were continued and covered a wide spectrum of subjects.

The proceedings of the Symposium on Sailing Yacht Research held in November, 1966, were issued as Technical Report 68-10.

FRANCIS RUSSELL HART NAUTICAL MUSEUM

On April 29, 1968, the Hart Nautical Museum held a reception on the occasion of the unveiling of a model of the U.S.S. Cochrane (DDG-21), named for Vice Admiral Edward L. Cochrane, a former head of the Department of Naval Architecture and Marine Engineering, who was responsible for the refurnishing of the Museum after the Second World War. Mrs. Cochrane unveiled the model for a group that included members of the Institute's administration, the Department's Visiting Committee and faculty, and many of Admiral Cochrane's old associates and friends. The model was constructed at the Naval Ship Research and Development Center, Washington, D.C., and is on a long-term loan to the Museum.

In connection with this reception a special exhibit, arranged in the corridor cases, featured water-line models loaned to the Museum by Mrs. Cochrane, and others obtained for the Museum by Admiral Cochrane. This exhibit included the newest model commissioned by the Museum, a 1/32-inch scale water-line model of the S.S. Manhattan, which was the first tanker of more than 100,000 tons deadweight built in the United States.

By a fortunate purchase late in June, a fine rigged model of the brigantine Newsboy, active in the Mediterranean fruit and West Indian rum, molasses, and sugar trades out of Boston in the 1870's was added to the Museum's collections.

Except for a few plans and books, notably the two-volume Marine History of the Pacific Northwest given by H. W. McCurdy '22, Course II, the Museum's other acquisitions through the year have been physical equipment. Roderick Matheson constructed the free-standing case in which the model of the U.S.S. Cochrane is displayed and a wall case that can be used for a variety of exhibits. Visitors have been pleased to note that M.I.T. has a craftsman capable of producing such excellent work. After consultation with Earl M. Harvey, the Institute's staff architect, new draperies were ordered and installed in the Museum.

Other special exhibits during the year have included the America's Cup yachts, early fishing vessels, "The New Wave at M.I.T." featuring the Towing Tank, and early submarines and modern deep-sea research vehicles. Three models on loan from the U.S. Navy, the Bonhomme
Richard and the cruisers Brooklyn and Chicago were recalled and two models of early fishing vessels borrowed from the Peabody Museum of Salem were returned.

Because of the type of paper produced in the late nineteenth and early twentieth centuries, many of the Herreshoff plans are in poor condition. Nine of the worst of them have been treated to reduce acidity and strengthened with a special backing; this procedure will be continued as funds permit. By way of further protection, all the plans in the collection are being transferred to folders of special acid-free stock. Five of the Benjamin Russell water color paintings in the Forbes Collection are undergoing treatment for the same acid condition. A large oil painting of the S. S. Massachusetts has been cleaned and restored.

The Museum continues to receive favorable publicity. It was the subject of a special article in the January, 1968, issue of Tech Engineering News, was mentioned in Marine Museums of the United States, published by the Maritime Administration in July, 1967, and received two pages in A Pictorial Treasury of the Marine Museums of the World, by Brandt Aymar. In a different vein, the Boston Public Library requested and received for distribution to its branches 35 copies of the booklet for the Clipper Ship show that was held in Hayden Gallery in the fall of 1966.

A special notice in the Yachting magazine issue of February, 1968, concerning the Museum's plan files, has resulted in an increase of mail inquiries and visitors seeking information for repairing and restoring old yachts, for constructing new ones, and for building models. As in other years there has been a continuous stream of visitors and mail and telephone inquiries on all sorts of maritime questions. During the year, at various times, we were pleased to welcome Mrs. H. Palmer, a daughter of Francis Russell Hart, for whom the Museum is named, her son, and his family.

William A. Baker, curator, has given the following seven lectures in the past year: on the development of American ships — at the Boston Public Library and to M.I.T. freshmen in The Birth and Care of a City (Boston), a subject taught by Professor Douglas P. Adams; On Elizabethan shipbuilding — to classes from the Weeks Junior High School, Newton; On Colonial American shipbuilding — at the Munson Institute, Mystic, Connecticut; and on the design of a late seventeenth-century ship — before the Welcome Society, Philadelphia, Pennsylvania.

The year has also seen the publication of a new brochure for the Department and a beginning of a Department history, both compiled by the curator of the Hart Nautical Museum.
Dr. Keil was appointed Chairman of the newly established Laboratory Advisory Board for Naval Ships by the Naval Research Advisory Committee. He became a member of the Naval Warfare Panel of the President's Science Advisory Committee in 1967, a Councillor of the Massachusetts Chapter of the Marine Technology Society and a member of the Ocean Engineering Committee of the National Academy of Engineering.

Professor Frankel was given responsibility for the technical direction of the Litton Industries Advanced Marine Technology Division during his leave of absence from July, 1965, to July, 1967. This direction included the development of the new Ingalls West Bank Shipyard, currently under construction, and the winning proposal for the production of the Navy's FDL (Fast Deployment Logistics) and LHA ships.

Professor Mandel became a member of the Vehicles and Platform Panel of the Ocean Engineering Committee of the National Academy of Engineering; also, he became a member of the Panel on Energy Sources, Committee on Undersea Warfare of the National Academy of Sciences.

During the last academic year Captain R. Stark, USN, served as Chairman of the New England Section, The Society of Naval Architects and Marine Engineers.

ALFRED A. H. KEIL

DEPARTMENT OF NUCLEAR ENGINEERING

The most significant influence on the program and activities of the Department of Nuclear Engineering continues to be the rapid pace of installation of nuclear power stations by electric power companies. The number and total capacity of nuclear generating units ordered by U.S. power companies has been increasing as follows:

<table>
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<tr>
<th>Year</th>
<th>Number</th>
<th>Capacity, megawatts</th>
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<tbody>
<tr>
<td>Prior to 1965</td>
<td>19</td>
<td>4,004</td>
</tr>
<tr>
<td>In 1965</td>
<td>7</td>
<td>4,234</td>
</tr>
<tr>
<td>In 1966</td>
<td>21</td>
<td>16,618</td>
</tr>
<tr>
<td>In 1967</td>
<td>25</td>
<td>20,184</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>45,040</td>
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By April 1, 1968, the number of units on order or planned had increased to 99, with a total capacity of 70,000 megawatts. The Atomic Energy Commission (AEC) predicts that the total installed nuclear capacity in
the United States will have increased to 145,000 megawatts by 1980, and to 734,000 megawatts by 2000. This may be compared with the total U.S. generating capacity of all types of 268,000 megawatts on January 1, 1968.

Thus, within the professional lifetime of today's engineering students, the equipment manufacturers and power companies of the United States will be installing and operating nuclear power stations, the combined capacity of which will be almost three times that of the present U.S. electric power industry.

The rapid growth of nuclear generating capacity in the United States is paralleled in many other industrialized countries, notably England, France, Germany, the U.S.S.R., and Japan. In countries where conventional fuels are scarce, such as Japan, the development of nuclear power has an added element of urgency.

Engineering studies are demonstrating that the cost of electricity from a nuclear power station should continue to decline as the size of the station is increased. This has given rise to the concept of an energy center, in which the output from one or more very large nuclear power stations would be used by a complex of energy-intensive industries, located where shipping costs of raw materials or finished products could be minimized.

One of the most appealing potential applications of such a nuclear energy center would be to distill large amounts of fresh water from the ocean while producing low-cost electricity as a by-product. In desert regions of the world adjacent to the ocean where the land is fertile and the growing season long, such as in Australia, India or the Middle East, engineering studies are showing that fresh water can be produced in this way at costs sufficiently low to permit its use for irrigation of food crops, provided that the agricultural methods practiced make more efficient use of water than those conventionally used today. At the same time, the by-product electricity from these energy centers can be used to produce fertilizers and to power other energy-intensive industries. In this way, low-cost nuclear energy holds promise for increasing the world's food supply while facilitating the growth of industry in parts of the world where development has been hindered by lack of low-cost energy.

Present and potential uses for nuclear energy provide challenging opportunities for graduates trained in nuclear engineering and have created a strong demand for persons with this training. The Department of Nuclear Engineering familiarizes students with the scientific, engineering and economic characteristics of light-water reactors, the type principally being used in today's U.S. nuclear power plants. In addition, students are acquainted with the characteristics of more advanced types of reactors,
such as the fast breeder reactor, which will produce up to one hundred times as much energy as a light-water reactor from a given amount of uranium and may provide further substantial reductions in nuclear energy cost.

The interests of the Department of Nuclear Engineering extend beyond nuclear power plants. The Department is active in other related areas of advanced technology, including applied radiation physics, low-energy nuclear physics, radioisotope applications, radiation effects on materials, nuclear rockets and other nuclear energy systems for space application, thermionic direct conversion devices, and applied plasma physics. About one-fourth of the Department's faculty, students and research budget is devoted to applied plasma physics because of its relation to controlled thermonuclear fusion of light elements, and other important applications.

If a feasible and economic power plant based on the controlled fusion of light elements could be developed, the world would have a second practically inexhaustible source of energy, rivaling the breeder reactor. Although the feasibility of a fusion power system is yet to be fully demonstrated, and its economics can hardly be guessed at, understanding is being gained on how such a system might operate and what it would look like. The system now judged most likely to be feasible consists of a plasma of fully ionized heavy hydrogen atoms at a temperature of millions of degrees, confined by specially shaped magnetic fields. During the past year progress has been made in understanding the conditions necessary for stable plasma confinement, and engineering studies suggest that energy costs could be in a reasonable range.

Through its program of instruction and research in applied plasma physics, the Department of Nuclear Engineering is making significant contributions to the national effort on controlled fusion research. At the same time, this work is providing a better general understanding of plasmas and is contributing to the development of other applications of plasmas, such as to high-intensity gas lasers and a novel type of intense neutron generator. Graduates of the Department's applied plasma program are filling responsible positions in universities, national laboratories, and industrial research centers.

STUDENTS

During the past year 27 students received the degree of Master of Science in Nuclear Engineering, two the degree of Nuclear Engineer and 13 the doctor's degree. The number of each type of degree was slightly smaller than in the preceding year.

In September, 1967, the enrollment in the Department was 132 regu-
lar students and four special students, a total of eight more than in the previous year. About one-fourth of the students were from abroad. As in previous years, the number of students has been determined mainly by the amount of financial support the Department is able to offer plus the number of students who bring financial support with them in the form of fellowships or other educational grants. Because of reductions in the amount of financial support the Department can offer owing to cutbacks in Federal funding of research, and because of the change in Selective Service regulations which makes many graduate students no longer draft deferrable, the number of graduate students enrolled in September, 1968, will perhaps be 15 lower than in previous years. This trend is expected to continue for several more years unless government policy regarding support of research at universities and the military obligations of graduate students is changed. The anticipated reduction in the number of men receiving education in nuclear engineering is especially regrettable in view of the rapidly increasing national need for men to design, build, operate and improve the many nuclear power plants now on order or being planned.

FACULTY

The main strength of the Department of Nuclear Engineering is its capable, dedicated and well-informed faculty. The principal ways in which members of the faculty keep abreast of new developments in a field advancing as rapidly as nuclear engineering is by the conduct of research, by participating in technical meetings and the affairs of technical societies, by undertaking professionally valuable consulting work, and by occasional well-planned sabbatical leaves. The research programs of the Department will be described later; here some of the other constructive activities of the faculty will be mentioned.

Professor Henri Fenech was on sabbatical leave in the spring term and received a North Atlantic Treaty Organization (NATO) Fellowship that permitted him to visit the principal nuclear centers of Western Europe. His longest stay was at the French fast reactor development center at Cadarache, where he took part in safety experiments on water-cooled and sodium-cooled reactors.

During the fall term Professor Elias P. Gyftopoulos spent his sabbatical leave at ThermoElectron Corporation. There, he participated in development work on thermionic energy conversion devices for nuclear reactors and continued writing a textbook on thermionic energy conversion.

Professor Edward A. Mason spent six months at Oak Ridge National Laboratory as director of an interdisciplinary study for the U.S. Atomic
Energy Commission on the possible impact of low-cost energy on industry and agriculture. The potential low cost and ubiquity of nuclear energy is eventually expected to play a major role in the location of chemical and metallurgical plants. Nuclear reactors will bring cheap energy to sources of bulky raw materials, thus eliminating much of today's transport of these raw materials to sources of cheap electricity. Cheap electricity can also be used to conserve mineral resources; two examples are the electrolytic production of nitric and hydrochloric acids to substitute for sulfuric acid and thus save sulfur, and the electrolytic production of hydrogen to substitute for hydrogen from petroleum, natural gas, or coal. One aspect of the study considered the production and use of electricity and desalted sea water in large nuclear-powered agro-industrial complexes. Such nuclear-powered complexes would provide large-scale, integrated production of fertilizers, metals, basic chemicals, and various irrigated agricultural crops. They may offer special opportunities for developing countries to make use of their natural resources and to accelerate their industrial, agricultural, and economic development.

Professor David J. Rose spent the first half of the academic year on leave at the Oak Ridge National Laboratory and the second half at the Culham Laboratory of the United Kingdom Atomic Energy Agency. His principal activity has been an in-depth engineering study of the probable characteristics of a controlled fusion power system. Feasible values of ion and electron energies, fractional conversion per pass of the deuterium-tritium nuclear fuel, dimensions of the reaction vessel and equipment for recovering heat and neutrons and other system characteristics were determined, and rough cost estimates were made. The most attractive system is large, of the order of 10,000 megawatts electric. The cost of electricity from such a fusion system could be less than from a breeder reactor because fuel costs are less, no radioactive fission products are made, dimensional tolerances are less exacting and the yield of excess neutrons may be large. If the central problem of providing stable plasma confinement can be solved, fusion power will merit serious consideration.

Four members of the faculty have given invited papers at international conferences. Professor Gordon L. Brownell attended a symposium on Radioisotopes in Medicine, at Bad Gastein, West Germany. Professor Thomas H. Dupree was a U.S. delegate to international symposia on shock waves in plasmas in Novosibirsk, U.S.S.R., and on contemporary physics in Trieste, Italy. Professor Gyftopoulos presented two papers, an invited paper on surface theories and another paper on a quantum mechanical interpretation of electron emission from surfaces, at an international conference on thermionics in Stresa, Italy. Professor Sidney Yip
gave a paper at the symposium on inelastic neutron scattering, sponsored by the International Atomic Energy Agency, in Copenhagen.

Members of the faculty are very active in the American Nuclear Society. Professor Brownell was elected Vice Chairman of the Isotopes and Radiation Division. Professor Gyftopoulos is a Director of the society and has been elected Fellow and Vice Chairman of the Aerospace Division. Professor Kent F. Hansen has served as Vice Chairman and has been elected Chairman of the Mathematics and Computation Division. Professor Theos J. Thompson has been elected Vice Chairman of the Reactor Physics Division.

Professor Thomas O. Ziebold is currently serving as a member of two technical committees whose responsibility is to develop industry codes and standards for nuclear power stations. One of these committees, under the auspices of the American Society of Mechanical Engineers (A.S.M.E.), is writing a code applicable to the construction of pump bodies and valve casings for nuclear plants. The other committee, sponsored by the U.S.A. Standards Institute, has the general responsibility for establishing standards for the location, design, construction and maintenance of nuclear reactor plants. One of the principal interests of this committee at the present time is the difficult but critical question of developing standards for in-service surveillance of pressure vessels and other pressure-retaining components in light-water reactor systems.

A few examples will illustrate the diversity and value of consulting work undertaken by members of the faculty. Professor Fenech serves as consultant on gas-cooled power reactors with Gulf General Atomic. Professor Hansen serves as consultant on numerical analysis in nuclear reactor design for several leading reactor manufacturers. Professor Mason is a member of the joint U.S.-Canadian Technical Advisory Committee, which coordinates research on heavy-water reactors, sponsored by the Atomic Energy Commissions of the two countries. Professor Norman C. Rasmussen acts as technical advisor to the Nuclear Energy Property Insurance Association, rendering assistance in evaluation of risks and in the settling of claims resulting from accidents involving nuclear materials. Professor Thompson acts as consultant on nuclear reactors and nuclear power plant safety for a number of reactor manufacturers and electric power companies in this country and Sweden. Professor Yip is a consultant on neutron scattering at the U.S. Army Materials and Mechanics Research Center.

There have been a few personnel changes in the Department. Professor Elmer E. Lewis, who has served for two years as Postdoctoral Fellow in Engineering and Assistant Professor, has accepted a position as Assis-
stant Professor of Nuclear Engineering at Northwestern University. Professor Lewis' contributions in reactor physics and neutron transport theory have been valuable and are appreciated.

Dr. Norman L. Oleson, Professor of Physics at the U.S. Naval Postgraduate School at Monterey, California, has served as Visiting Professor at M.I.T. during the past year and has made valuable contributions to the program of research and instruction in the plasma and controlled fusion field while Professor Rose was on leave.

Dr. N. Thomas Olson, formerly Assistant Professor of Nuclear Engineering at the University of California at Berkeley, has joined the Department as Postdoctoral Fellow in Engineering and Assistant Professor. Professor Olson's interests have been in experimental physics and the interaction of beams of particles with solids.

INSTRUCTION

The Department's subjects of instruction are in two principal fields. One group of subjects deals with the technology of nuclear fission, the reaction utilized in today's nuclear power reactors. The other group deals with plasmas and controlled fusion.

In the fission technology field, Professor Irving Kaplan has been perfecting a series of three subjects dealing with the physics of nuclear reactors and has been preparing a set of notes to serve as an up-to-date text on this subject. Professor Fenech has been preparing a second set of notes dealing with the engineering aspects of nuclear reactors, a topic on which there is now no satisfactory text.

Professor Thompson has been developing a sequence of two subjects being given in alternate years, one dealing with fast breeder reactors and the other with thermal power reactors. During the fall of 1967 the thermal reactor subject was offered for the first time. It described the reactor engineering and reactor physics aspects of large nuclear power reactors operated principally by thermal neutron fission. Up-to-date descriptions of thermal neutron power reactors were presented, including their current status and design and operational problems. Safety considerations were discussed and possible future reactor designs were outlined. The class was organized into three teams to compete in a design competition. Bids were requested from each of the three groups in the name of a fictitious country bordering on the Mediterranean. One group designed a gas-cooled reactor, the second a pressurized or boiling water reactor, and the third a heavy water reactor of the type favored in Canada. A jury of eminent reactor authorities from M.I.T. and elsewhere listened to the proposals and made a final selection. Two or three possible
SCHOOL OF ENGINEERING

patentable ideas were developed during the course of the competition.

In the spring term Professor Michael J. Driscoll supervised a class which undertook a more detailed engineering study of an advanced type of heavy water reactor designed as a thermal breeder on thorium fuel. At today's uranium price, the class found that the capital and the energy costs of the reactor are higher than those of light water reactors.

Professor Thompson's subject in reactor operations is becoming still more complete, as additional power reactors come on the line to serve as examples. After receiving instruction in the techniques of nuclear reactor operation, including initial fuel loading, criticality considerations, reactivity measurements, operating experience, and reactor safety problems, the students participated in startup and operation of the M.I.T. Reactor, including all of the principal maneuvers. The class visited the Yankee Atomic Electric Company's plant during its refueling period and the Connecticut Yankee plant during normal full power operation. They also visited the site of the Millstone plant of Northeast Utilities, which is currently under construction. These plant visits, coupled with the operation of the M.I.T. Reactor, gave each student a very realistic view of the operation and control of large nuclear power stations.

During the summers of 1966 and 1967, Professor Thompson directed a two-week Special Summer Program titled "Water-Cooled Power Reactor Safety." In 1966, 94 participants attended from the United States and a number of foreign countries. In 1967, 104 students participated. The participants represent the technical and engineering staffs of electrical power utilities, reactor manufacturers, government regulatory agencies, national laboratories, and research organizations. Lectures were presented by outstanding authorities on nuclear power reactors from M.I.T., the principal reactor manufacturers, and the AEC. For 1968, the Program has been broadened to include a second part on "Fast Nuclear Power Reactor Safety." The second part emphasizes the sodium-cooled fast breeder concept. In recognition of the international activities on fast breeder technology, lecturers from Great Britain and France have been invited to present reviews of their prototype reactors and their future national plans from the reactor safety viewpoint. In addition, key representatives of all of the fast breeder reactor prototypes in the United States will give lectures. For these summer programs, the text is the two-volume compendium, The Technology of Nuclear Reactor Safety, edited by Theos J. Thompson and James G. Beckerley. Professors Ziebold, Driscoll and Thompson are lecturers from M.I.T.

The principal change in the plasma instructional program has been Professor Dupree's revision and updating of the classes in plasma kinetic
theory to emphasize new areas of current theoretical interest. The fall
class will now be offered jointly with the Department of Physics and the
spring class with the Department of Aeronautics and Astronautics.

In the summers of 1967 and 1968, Professor Franklyn M. Clikeman
introduced a new laboratory subject, Basic Electronic Instrumentation.
This is intended to give students in both the reactor technology field
and the plasma field, who had little or no background in electronics, a
working knowledge of electronic circuits and devices. This summer
laboratory offering has filled a real need, as it was oversubscribed in
1967 and 1968.

M.I.T. RESEARCH REACTOR

The M.I.T. Research Reactor continues to be the most important
research facility of the Department of Nuclear Engineering. It is also
used extensively as a radiation source for research by other M.I.T. de-
partments and New England organizations outside M.I.T.

The Reactor has now completed ten years of useful operation. Follow-
ing initial criticality on July 21, 1958, one year was utilized for flux
measurements, calibration, low power tests and one-shift operation.
During the subsequent nine years the Reactor has been operating on a
regular three-shift schedule from Monday morning to Friday evening,
with weekend shutdowns for maintenance, fuel changes, and experiment
installation.

Normal full-power operation was initially set at 1 MW (megawatt).
This was raised to 2 MW in July, 1961, and, after installation of addi-
tional cooling capacity, to 5 MW in November, 1965. These increases,
along with other modifications to the reactor experimental facilities, ir-
radiation ports, process systems, and auxiliary equipment, have increased
its usefulness and versatility very significantly in recent years. Further
renovations and improvements completed during the year, or now in
progress, include the installation of a fast reactor blanket facility, a
helium refrigeration system to permit irradiation of samples at 4°K,
and moderation of neutrons at 20°K, an inelastic scattering spectrom-
eter, and a high-resolution gamma-ray spectroscopy port for measure-
ment of neutron-capture gamma rays and for prompt activation analysis.
Research using these new facilities is described in later sections of this
report.

During the past year the Reactor continued to operate safely and
reliably for an average of 95 hours per week, thanks to the dedicated
efforts of the reactor staff headed by Professor Thompson, Director,
Lincoln Clark, Associate Director and Business Manager, Edward J.
Barnett, Assistant Director for Engineering and Design, and James W. Gosnell, Assistant Director for Operations.

Within M.I.T., the Departments of Nuclear Engineering, Physics, Chemistry, Metallurgy and Materials Science, and Geology and Geophysics continue to support active research programs at the Reactor. The M.I.T. Instrumentation Laboratory has initiated a series of irradiation effects studies, and other laboratories and departments make intermittent use of the Reactor. About 60 students annually have been engaged in research based on the Reactor and its related experimental projects, and another 60 enroll in the several laboratory subjects that utilize the Reactor. Almost all of these are graduate students.

During the past year, other colleges and universities have sent materials to the M.I.T. Reactor for irradiation. These included Amherst College, Boston College, Brandeis University, Carnegie-Mellon University, Harvard University, University of Hawaii, University of New Hampshire, University of Rhode Island, and Woods Hole Oceanographic Institution. A total of 23 educational institutions and other research centers have used the Reactor periodically during its decade of operation. Of the three hospitals and 30 industrial firms which have used the Reactor in the past, most are still regular or intermittent customers. The Reactor serves educational needs of the community by employing Northeastern University Cooperative Students and by other means, such as providing guided tours for schools, colleges, professional organizations, civic groups, and others.

Financially, the Reactor has come within 3 per cent of balancing its ten-year operating budget. Funds received from users and the costs of operation for the total period and for the two most recent years are given below. (At the time of writing, final figures for 1967-68 were not available).

<table>
<thead>
<tr>
<th></th>
<th>Ten Years 1958-68 (Estimated)</th>
<th>1966-67</th>
<th>1967-68 (Estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receipts</td>
<td>$2,685,000</td>
<td>$289,077</td>
<td>$276,000</td>
</tr>
<tr>
<td>Expenditures</td>
<td>2,753,000</td>
<td>277,134</td>
<td>311,000</td>
</tr>
<tr>
<td>Difference</td>
<td>-68,000</td>
<td>11,943</td>
<td>-35,000</td>
</tr>
</tbody>
</table>

Half of the over-all deficit has been incurred during the last year, although fluctuations of this magnitude and larger have been experienced since the start of operation. Limitations on the availability of research funds and revisions in AEC research objectives have been primarily responsible for the recent deficit.
The design of the Reactor has facilitated modifications to support a more varied and updated research program. In addition to the renovations mentioned above, design studies have been initiated for the purpose of installing a completely redesigned core, which will increase the neutron flux levels substantially without any increase in reactor power. This and smaller modifications in the past are made possible through a fund which M.I.T. has been accumulating specifically for such purposes. M.I.T. is indebted to many additional sources for operating support and for loans of materials and equipment, including in particular the Sloan Fund for Basic Research, the Atomic Energy Commission, and the National Science Foundation.

In the proposed modification of the Reactor, the core will be made more compact and the central region of the Reactor will be redesigned and rebuilt. In this way it is expected that the useful neutron flux will be increased by a factor of about five without any increase in reactor power. The redesigned Reactor should be superior for neutron spectroscopy to every reactor in the United States with the exception of the Brookhaven High Flux Beam Reactor. The cost to experimenters per neutron used should be substantially reduced by this redesign. Currently, the detailed design is being carried forward by a full-time team of four graduate students, with part-time help from several others working on the detailed calculation. Project leadership and guidance are being provided by Mr. Barnett, Mr. Gosnell, Mr. Clark, David F. Frech and Professor Thompson.

It is anticipated that design will be completed early in the fall of 1968. Negotiations with the AEC for safeguard permission to make this renovation and with contractors for fabrication of the components will be carried out during the fall of 1968. Fabrication will occur during the first half of 1969 and installation is planned for the latter half of 1969.

RESEARCH AT THE M.I.T. REACTOR

Since 1959, under AEC sponsorship, M.I.T. has conducted a comprehensive theoretical and experimental program of research on the reactor physics properties of lattices of slightly enriched uranium fuel in heavy water moderator. Neutrons needed to drive the subcritical assemblies studied in this project were obtained from the thermal column of the M.I.T. Reactor.

On September 30, 1967, the work of this Heavy-Water Lattice Project was completed. In addition to obtaining a great deal of data on slightly enriched uranium fuel, one major result of this project was to show that it appeared feasible to develop methods using single-fuel rods, or a few
rods, for predicting characteristics of an entire array of fuel rods. This is an important development, since new types of power reactor fuel can be studied without requiring a large number of fuel rods. M.I.T. therefore proposed further work in this specific area, and a new Reactor Physics Project was approved by the AEC effective January 1, 1968.

The Reactor Physics Project, which is budgeted at about 50 per cent of the level of its predecessor, has as its primary objective the perfection of single-rod techniques and their application to scarce fuel types, such as plutonium recycle fuel elements, and hard-to-handle materials such as highly radioactive partially burned fuel elements. It is anticipated that this work will provide information on possible new and more efficient power reactor fuel assemblies. In addition to use of foil activation techniques, an important area of research will be the use of high-resolution Ge(Li) gamma spectrometry to determine reactor physics parameters.

Professors Driscoll, Rasmussen, Thompson, and Kaplan are involved in this new research project; under their supervision two doctoral students and one Master's student have begun thesis research to date.

A new facility is being constructed at the M.I.T. Reactor to permit expanded research in the area of fast breeder reactor physics. The facility design is being carried out by a doctoral candidate, under the supervision of Professors Driscoll and Thompson. The heart of the facility consists of a large (20 ft.²) fission plate and appropriate diluents which partially degrade the fission neutron energy spectrum into a spectrum typical of a fast reactor core. The resulting converter assembly is installed in an irradiation cave outside of the thermal column. The converter assembly in turn feeds neutrons into an adjacent blanket test assembly which simulates a typical fast reactor blanket. The blanket of a fast breeder reactor surrounds the core and is the region in which much of the net plutonium product is made. Hence, its characteristics are very important to the economics of the fast breeder reactor concept.

In this new facility it is possible to obtain a full range of neutron energies, from very high (near the converter) to relatively low (deep inside the blanket), in which to conduct physics experiments. The converter fission power of 100 watts is about one hundred times that of typical fast critical assemblies, and thus the facility should be able to compete very favorably for many applications.

Construction of the facility has been started, and completion is anticipated in the fall of 1968. Approximately $25,000 of M.I.T. funds has been budgeted for this purpose.

Initial applications planned are:
1. Use as a test bed for development of fast neutron spectrometers
2. Irradiation of simple blanket mock-ups of possible fast breeder reactors to provide integral results against which to test calculational methods
3. Use as an irradiation facility by M.I.T. Instrumentation Laboratory research workers studying the effect of fast neutron irradiation on transistorized equipment packages
4. Doppler effect measurements
5. Development of methods to optimize the economics of breeding by modifications of the blanket region

The Organic Coolant Project completed its study of the effects of fast neutron and gamma radiation on mixtures of terphenyl isomers. Due to their low vapor pressure and compatibility with ordinary steel, these organic fluids are of interest as coolants for nuclear reactors, although they undergo some decomposition in the reactor environment. Changes in these coolants due to heat and radiation have been studied by Professor Mason and his students by continuously circulating coolant through a loop installed inside a fuel element in the M.I.T. Reactor. This past year a correlation has been developed which permits the prediction of the rates of degradation of various mixtures of the terphenyl isomers allowing for changes in temperature, the relative dose rates from fast neutrons and gamma rays, and coolant composition. No effect of total dose rate on the rates of decomposition was observed. As a result of these studies, which have been sponsored by the Atomic Energy Commission, the rates of coolant degradation and required coolant makeup, the physical properties, and the heat transfer characteristics for reactor systems using terphenyl coolants can be predicted and organic coolant systems for nuclear reactors properly designed and optimized.

During the last year a small loop was built in the thermal column of the M.I.T. Reactor to study the chemical form and reaction behavior of nitrogen-16, the principal short-lived radioisotope formed in the water used in water-cooled reactors. With a $2,500 grant from the Sloan Fund, Professor Driscoll and a student built the loop and demonstrated that more than 75 per cent of the nitrogen-16 is in ionic form and hence can be removed by a mixed-bed ion exchanger.

Mr. Barnett and Professors Thompson and Olson and their students have essentially completed the construction of a cryogenic facility in the thermal column of the M.I.T. Reactor. The facility is designed to chill a block of neutron moderating material to about 20° Kelvin in order that neutrons entering the material will be slowed and then be made available for experimental purposes. This first cold neutron source will be utilized as the test facility to optimize the design of a final source, which is to be
inserted while the Reactor is shut down for renovation. It is believed that the available cold neutron flux intensity from this facility will be comparable to that available in any other facility in the world.

The slow-moving neutrons from this low-temperature source will be channeled selectively from the source to facilities outside the thermal column by internal total reflection in bent polished metallic tubes. Low velocity neutrons are reflected internally within such a tube, very much as light is reflected in a light pipe. These neutrons will make possible a new host of experiments at the M.I.T. Reactor. An example is experiments on slow neutron transmission and reflection within single crystals, such as those conducted recently by Professor Clifford G. Shull of the Department of Physics. Another example is the experimental determination of the electric dipole moment in the neutron.

A number of experiments based on magnetic resonance frequency measurements in a neutron beam have been carried out within the past few months. These measurements show that the value of the electric dipole moment must be less than $10^{-21}$ e cm. The accuracy of the measurements depends upon the length of the time a neutron is in the magnetic resonance field and hence depends inversely upon the velocity of the neutron. Hence, slow-moving neutrons are more effective than faster neutrons. Thus, the accuracy of this type of measurement as well as many other measurements will be enhanced considerably by use of very slow moving neutrons. These typical examples of possible experiments indicate some of the reasons for the interest of the nuclear reactor staff in creating an intense source of slow-moving neutrons.

Professor Ziebold and his students have designed a cryostat for irradiating materials cooled by liquid helium in the center of the M.I.T. Reactor core. The interest in this low-temperature irradiation is to "freeze in" the primary crystalline defects produced by fast neutron bombardment. Subsequent measurements of the annealing kinetics when a sample is warmed in a controlled fashion provide an insight into the nature of point defects in solids, of their mobility, and of their interactions with other structural defects.

It is planned to use slow-moving neutrons from the cold moderator source described above in neutron scattering experiments on materials irradiated at low temperatures. The long wavelength of these slow neutrons should provide unique information on the characteristics of radiation-induced point defects in solids.

At the present time, construction of the Reactor cryogenic facilities is approximately 75 per cent complete, and we are awaiting approval
from the AEC to operate the refrigeration plant within the Reactor containment.

Professor Ziebold and his students, in cooperation with the Naval Research Laboratory, have recently initiated a study of fracture behavior of steels used for nuclear reactor pressure vessels. The principal research tool used in this work is the scanning electron microscope which makes possible the examination of bulk fracture specimens. We expect to apply this instrument to the examination of irradiated steels in an effort to correlate fracture appearances with the reduction in fracture toughness which is produced by neutron irradiation. The work is being supported at M.I.T. by the Office of Naval Research.

Professor Rasmussen and his students have continued development of high-resolution gamma-ray spectroscopy using Ge(Li) detectors and their applications to nuclear engineering problems. Measurements of the capture gamma-ray spectra of 75 elements have been completed at the M.I.T. Reactor. This work represents the most complete study of capture gamma-ray spectra presently available.

With support from the U.S. Bureau of Mines, Professor Rasmussen and his students have initiated study of the possible use of neutron capture and inelastic scatter gamma rays as a method for on-line analysis of coal. With Professor Brownell, work is being continued on the biomedical applications of prompt activation analysis using capture gamma rays. Up to 12 trace elements in a biological sample can be analyzed without chemical separation.

With AEC support, Professors Driscoll and Rasmussen are conducting research in the development of non-destructive techniques for the analysis of spent reactor fuel. It is hoped that these techniques will be valuable to power reactor operators and fuel reprocessors in providing means for assaying spent fuel before reprocessing. These techniques may also prove useful in the international control of fissile materials.

RESEARCH WITH THE ROCKEFELLER ACCELERATOR

The 3.5-MeV Rockefeller van de Graaff accelerator is being used under a grant from the National Science Foundation (NSF) to conduct research in the field of inelastic neutron scattering and neutron slowing down. The work is being carried out under the supervision of Dr. Leon E. Beghian and Professor Clikeman. Inelastic neutron scattering cross sections of materials of interest to fast reactor design are being investigated by measuring the gamma-ray production yield of the de-excitation gamma rays produced by inelastically scattered neutrons. High-resolution Ge(Li) gamma detectors, together with the pulsed-monoenergetic neu-
tron production by the accelerator, permit the gamma-ray yield curves and ultimately the inelastic neutron cross section to be determined with a precision that generally cannot be achieved with conventional neutron time-of-flight techniques.

Pulsed neutrons from this accelerator are being used in an investigation of the time-space-energy distribution of neutrons during the slowing down process. Professor Yip and a student are studying the theoretical aspects of the problem with the goal of predicting the time-space-energy neutron distribution.

A third experimental program, supported by the M.I.T. Center for Space Research and carried on with the help of Dr. Samuel J. Wilensky, has investigated the effectiveness of combinations of iron and paraffin to attenuate fluxes of 14-MeV neutrons. Monoenergetic neutrons are generated by the accelerator using the $^3$He$(d,n)^4$He reaction and the spectrum of the neutrons after passage through an iron-paraffin shield is measured by a proton-recoil scintillation detector. The ability to measure the neutron spectrum after passage through the shield has permitted a new insight to be gained in the problem of fast neutron shielding.

**REACTOR ANALYSIS**

With support from the AEC, Professors Gyftopoulos and Hansen and their students have begun work on a project to investigate problems in spatially dependent nuclear reactor kinetics. Two approaches are being followed: analytic models to describe the essential physics and to suggest experiments to permit verification, and numerical methods that are computationally feasible and that permit the analysis of various multidimensional reactor systems.

Professor Gyftopoulos and his students have continued theoretical studies of reactor dynamics and stability. Emphasis has been placed on the correlation between reactor power-burst characteristics and reactor design characteristics. The correlation is approached by means of dimensional analysis and the results so far are very encouraging.

Professor Driscoll and four thesis students are currently working on improved theoretical and numerical methods for analysis of fast reactors. Work is being focused on three major areas: the development of integral and modal methods as improved numerical calculation techniques; better descriptions of the inelastic and elastic scattering processes in fast reactor media; and development of simplified analytical models for fast reactor calculations.

Professor Yip and a student continued studies of the space, time, and energy dependence of neutron density during slowing down of fast neu-
trons. Using a flux synthesis method, it was possible to analyze in detail the effects of anisotropic scattering, source distribution, and energy dependence of the scattering cross section. These investigations provided partial theoretical support for the experimental program associated with the Rockefeller Accelerator. Results useful for the interpretation of slowing down measurements in water and graphite have been obtained.

RESEARCH IN REACTOR ENGINEERING

Professor Fenech and his students have conducted research on a number of reactor engineering topics. Experimental studies have been made on the vibration of nuclear reactor components induced by turbulent coolant flow and of transport processes taking place in two-phase flow in a vertical tube, such as occurs in a boiling water reactor. The latter study will help in understanding the occurrence of a critical heat flux in a nuclear reactor caused by drying out of the heated wall. A theoretical analysis of uncertainties in the thermal design of power reactors provides a more rational basis for setting safety factors than methods formerly in use. A dynamic programming technique has been applied to the problem of optimization of the management of control rods. The objective is to minimize non-uniformities in power density during fuel lifetime.

Professor Thompson and his students have conducted research on a number of topics related to reactor safety. One student demonstrated that there are upper limits to the amount of energy which could be released in a nuclear transient in a water-cooled reactor. Further refinement of this work may permit steps to be taken in siting power reactors closer to cities than is now considered prudent. A computer-aided analysis is being made of the loss-of-coolant accident in a water-cooled reactor. A combined experimental and theoretical investigation is being made of the effect of coolant voids on reactivity in a heavy water reactor, an important topic in the safety analysis of such reactors. A method is being developed for specifying the control procedure to be used in permitting a water-cooled power reactor to follow the load demand of a typical electric utility system.

Under NASA support through the M.I.T. Center for Space Research, Professors Mason and Hansen have continued direction of computer-aided studies of hydrogen-fueled nuclear rockets. Studies of the kinetics for neutronically coupled cores and of the transient analysis of nuclear rocket startup were completed. The effects of non-uniform uranium loading, coolant passage dimensions, coolant flow rates, and material properties on limiting rocket performance are now being considered.
Research on plasmas and controlled fusion in the Department of Nuclear Engineering is being conducted by Professors Dupree, Oleson, Rose and Lawrence M. Lidsky, and Dr. Ronald A. Blanken and their students as part of M.I.T.'s interdepartmental plasma research program administered by the Research Laboratory of Electronics, with financial support from NSF, the AEC, and the Department of Defense. In this work the Department of Nuclear Engineering has the two objectives of contributing to the eventual development of a fusion power system and of providing a better understanding of plasmas.

The key technical problem that must be solved before a fusion reactor can be built to produce useful amounts of power is to find how to provide stable confinement of a relatively dense plasma of deuterium and tritium ions at a temperature of around ten million degrees, in a strong, inhomogeneous magnetic field. Such a plasma is potentially liable to many types of instabilities, which are the subject of much of the research on plasmas being done in this Department and elsewhere.

To study the properties, confinement and instabilities of plasmas, a hollow-cathode arc plasma source has been developed and is being used extensively for research. During the last year, one of the principal instabilities seen in the arc plasma column was identified, together with its free-energy source. The properties of this "current-driven drift wave" are now under careful investigation for comparisons with theoretical predictions of threshold and non-linear limits. The radial electric field in the plasma column has been accurately measured for the first time and used to calibrate a newly developed scheme for the direct measurement of the rate of leakage of plasma from the confining magnetic field.

One of the principal means under development for following small-scale fluctuations in plasmas is scattering of light from high-intensity laser sources. Professors Rose and Lidsky and their students have been investigating the properties of a high-power carbon dioxide laser, which itself constitutes an interesting field for plasma research. With such a laser it has been possible to detect the light scattered by an arc plasma, and efforts are now being made to determine the spectrum of the scattered light.

A non-linear theory of transverse wave-particle interactions based on Professor Dupree's work for the longitudinal wave case has been completed and will be tested experimentally in a recently completed particle trap. This device uses electrostatic mirrors to trap electrons in a long vacuum chamber where they interact for known periods of time with magnetic field perturbations and are then energy-analyzed to determine...
their change in velocity. The parameters for this experiment have been chosen to allow comparison with strong turbulence theory.

Professor Dupree's theoretical research on plasma turbulence and non-linear fluctuations is providing valuable insight into plasma instabilities and associated phenomena such as fluctuation amplitudes, enhanced escape of plasmas from confining fields, plasma acceleration by random processes, and emission of radiation from unstable plasmas. Excellent agreement has been obtained for several low-frequency instabilities that current limit containment in several confinement devices.

If the plasma confinement problem can be solved, one of the next most difficult problems of a fusion power system will be providing materials for the wall of the vessel to contain the reacting plasma. This wall must stand up under intense fluxes of heat, X rays and 14-MeV neutrons. The neutron flux will be much higher than is obtainable in any existing laboratory test devices. Professor Ziebold and his students are investigating radiation damage by the lower flux of 14-MeV neutrons obtainable from the Department's present accelerators. Professor Lidsky and his students are completing a design study of a novel high-intensity 14-MeV neutron source. In this device a high-intensity beam of tritium ions from an accelerator would react with a hypersonic jet of deuterium gas flowing through a nozzle from a region of high density into a vacuum. The fusion reaction between deuterium and tritium which produces 14-MeV neutrons would take place in the small volume in which the deuterium density was changing most rapidly. It appears possible to reach steady neutron fluxes in excess of $10^{15}$/cm$^2$-sec. within the present limits of wind-tunnel and ion-acceleration technology.

**OTHER RESEARCH**

The major research activities of Professor Yip and his students this last year continued to be studies of time correlation functions in gases and liquids, with application to radiation scattering experiments and transport phenomena. The specific problems considered dealt with the analysis of inelastic neutron scattering measurements, the analysis of Rayleigh scattering of laser light and the evaluation of thermal transport coefficients in dense fluids. A number of interesting results emerged from these investigations; among these were exact initial-value solutions to the linearized Boltzmann equations for atoms interacting through repulsive potentials and a new method for calculating the shear viscosity of simple liquids. This work has been supported by the National Science Foundation and the U.S. Army Research Office–Durham. Funds have been secured from the Sloan Foundation to permit design and construc-
tion of a triple-axis neutron spectrometer to perform inelastic neutron scattering experiments which will complement Professor Yip's theoretical research.

Professor Gyftopoulos, in collaboration with Dr. George N. Hatso- poulos of the Department of Mechanical Engineering, has continued his theoretical research on fundamental phenomena in thermionic conversion. Three important results have been obtained. First, the electronega-
tivity of a spin-orbital of an atom has been identified with the negative of the electrochemical potential of the atom. The identification has been achieved by the application of statistical quantum mechanics to an en-
semble of one-atom members. Second, it has been shown that the elec-
tronic structure of a metal can be represented in terms of localized spin-orbitals. Third, it has been shown that the electronegativity of a spin-orbital localized around a lattice site at the surface of a metal equals the work function of the surface of the metal. These results are
of great importance to the understanding of thermionic emission phe-
nomena.

The Atomic Energy Commission has requested M.I.T. to seek means for producing heavy water at lower cost than in the dual-temperature hydrogen sulfide exchange process presently used. To this end, Pro-
fessors Manson Benedict and Mason and their students are investigating the monothermal ammonia-hydrogen exchange process, with liquid ammonia reflux provided by catalytic synthesis from hydrogen and nitro-
gen and with hydrogen stripping vapor made by cracking ammonia. By using as feed ammonia synthesis gas from a commercial ammonia plant producing 1,500 tons of ammonia per day, it would be possible to make about 100 tons of heavy water per year. Design studies and cost esti-
mates are being made to determine if the cost of heavy water in such a plant might be low enough to warrant further development of the process.

CONCLUSIONS

The foregoing description indicates that the Department is active in most of the areas in which nuclear energy will find practical application, both at present, and potentially in the future. The aim is to educate men and women for a lifetime of productive professional work in nuclear engi-
neering and for positions of technical leadership. The present heavy de-
mand for graduates in nuclear engineering, especially for the rapidly
growing nuclear power industry, is evidence of the national need for graduate education in this field. At the time when more men with this training are needed, it is thus most unfortunate that the number of men available for graduate study is being sharply reduced because of drafting
of graduate students and that Federal funds needed to support research by nuclear engineering graduate students are being cut back. Until these two adverse trends can be reversed, it is clear that the Department will not be able to make its full potential contribution to the development of nuclear technology.

MANSON BENEDICT

CENTER FOR ADVANCED ENGINEERING STUDY

The year 1967-1968 was highlighted by the occupancy of the Center’s new building. Fully air conditioned, this new facility contains faculty offices, study offices for participants in the Center’s programs, seminar rooms and classrooms, a high-speed digital computer laboratory, and a 170-seat lecture hall.

THE PRACTICING ENGINEER ADVANCED STUDY PROGRAM

The year 1967-1968 represented the fourth year of operation of the Practicing Engineer Advanced Study Program. The contributions made by the Fellows who participated in this Program in prior years, upon their return to their sponsoring organization, demonstrate the validity of the concept.

The Practicing Engineer Advanced Study Program is designed for men who have supplied and will continue to provide the initiative, leadership, and accomplishment that catalyze technical progress. The Program provides an opportunity for such people to spend one or more academic terms participating in any academic, research, or other M.I.T. activities that are relevant to their present and future needs. The purpose of sending a man to the Center is to prepare him for future responsibilities in his home organization. Because each man’s program is individually tailored, the Center is able to prepare men for future roles that encompass:

1. Technical management. The individual’s program combines work in key technical fields with work in relevant management areas.
2. Creative leadership in an area that demands the application of knowledge from several disciplines. The individual’s program is designed to add new fields to his current background.
3. In-depth accomplishment in one discipline. The individual’s program is tailored to lead to capability to extend the frontier of a discipline.

In the last four years, 60 men have completed this Program. Their median age has been 39. The majority of participants have been employees of industrial firms, but agencies of the Federal and local govern-
ment and sister universities have also sponsored fellows. The formal education backgrounds of the Fellows in the Program have encompassed aeronautical engineering, applied mathematics, chemistry, chemical engineering, civil engineering, electrical engineering, mechanical engineering, metallurgy, and physics. The study programs followed are tailored to meet the objectives of the individual and his sponsoring organization. No two individuals follow identical programs. Each program is designed, in the light of the background and future plans of the Fellow, as an optimum experience.

This flexibility is achieved by drawing on all of the educational resources of M.I.T. and, in cases in which greater scope is indicated, arrangements are made to include work at other educational and research activities in the metropolitan Boston area. No constraints are placed on the areas pursued. A Fellow is not restricted by disciplinary bounds but is encouraged to work at any level in any discipline that is commensurate with his background and objectives. The program of a Fellow of the Center often combines very advanced work in one area with studies at a basic level in another. Some participants carry a substantial load of formal classroom subjects; some work out, with the help of interested faculty, guided special study activities, and some dig deeply into research frontiers. The nucleus of the majority of the programs followed by the Fellows is built around the special subjects designed and offered by the Center to meet the needs of the mature professional.

THE PROGRAM IN SYSTEMATIC POLICY ANALYSIS

In cooperation with the Department of Political Science, the Center initiated a new full-academic-year Program in Systematic Policy Analysis. It represents a broadening of the Center's activities in systems technology to the public sector. The Program is designed to provide mid-career officials of Federal, state, and local government agencies with the capability to apply modern systems technology developments to the selection, organization, management, and operation of large public programs.

The program emphasizes the application of economic analysis, operations research and other quantitative methods to problems of public policy and management. As in the Practicing Engineer Advanced Study Program, the program is flexible and tailored to the background of the individual. However, a majority of the 1967-1968 fellows built their program around the special set of systems analysis subjects developed and offered by the Center to members of either the Practicing Engineer Advanced Study Program or the Systematic Policy Analysis Program.
INFORMATION PROCESSING SERVICES

Thirteen Federal government officials participated in the program in 1967-1968. They were sponsored by the following agencies: Department of Agriculture, Department of Labor, Department of Housing and Urban Development, Department of Health, Education and Welfare, Post Office Department, Federal Aviation Administration, Department of State, Department of the Interior, Bureau of Customs, Department of Defense, and the Civil Service Commission.

SHORT INTENSIVE PROGRAMS

During the summer of 1967, the Center offered two short intensive Programs: Probabilistic Methods and Civil Engineering Materials. Both programs attracted participants from industry and government and faculty participants from other universities.

The purpose of the three-week Program in Probabilistic Methods was to develop an understanding of the relevant fundamentals of the formulation and analysis of probabilistic situations. The emphasis of the Program was on the logical structure and range of applicability, not on advanced mathematical techniques. Each day was divided into lectures for the whole group (21 participants) and problem solving and discussion sessions in groups of four or five. Each small group was led by one of the teaching staff of the Program.

Eight of the participants were from business and industry, ten were from government organizations, and three were faculty members from other institutions.

The purpose of the two-week Civil Engineering Materials Program was to give civil engineers a fundamental understanding of structure-composition-properties relationships which would enable them effectively to assimilate new materials as they appear and to contribute to the development of new materials as the needs arise in engineering practice.

A total of 26 individuals attended the Program. Twenty-three were professors from 22 academic institutions.

ON-THE-JOB CONTINUED EDUCATION

The development of Probability Theory and Random Processes in a format designed for home-study use is continuing. The text and pilot films will be tested in the fall of 1968.

HAROLD S. MICKLEY

INFORMATION PROCESSING SERVICES

In the fall of 1967, the Institute made a major change in the organization within which its information processing and computer services are ad-
ministered. The primary outcome of this change was the establishment of a new office of Information Processing Services (I.P.S.) to coordinate the growth and development of the over-all information processing capability of the Institute. Under this new organization, the Institute will develop, for its various computer facilities, carefully coordinated and unified plans which are mutually supporting and which maximize our total strength in this important area.

Concurrent with this administrative change has been a growing awareness that we must consider our computer facilities in large part as service resources, and administer them so as to maximize their efficiency and effectiveness from the point of view of a large community of diverse users. In order to achieve these objectives, our efforts during the last nine months have been focused on two major goals:

1. The strengthening and reorganization of the central computer facility that had existed in a continually expanding form at M.I.T. since 1956 as the Computation Center; and
2. The formulation of the basic guidelines under which our unified plans will be developed.

In the remainder of this report, our achievement in these areas during the last nine months and our plans for the coming year are discussed.

CENTRAL FACILITY

In recognition of its changed role, the Institute’s Computation Center was redesignated as the Information Processing Center. The change, however, has been far more than one of name only.

The Center’s staff has been reorganized into five functional groups, charged respectively with administration, programming, operations, physical planning, and user services. Within this framework, the Center has offered its users two major categories of service during 1967-68. The first of these, time-sharing, is supplied by the modified IBM 7094 operated on a 24-hour-a-day basis under the Compatible Time-Sharing System (CTSS) developed at the Institute. The second service, batch processing, is provided by an extensive IBM System/360 installation that includes a Model 65 and a Model 40 operating in an Attached Support Processor (ASP) configuration.

The CTSS system has now been in fairly stable operation for several years. The only significant changes made during the past year were directed first at making the system operated at the Center identical with the similar system operated at Project MAC and second at implementing at the Center the comprehensive accounting and system administration subsystem developed at Project MAC.
The System/360 installation, on the other hand, has undergone a number of significant changes. These included first the continuous updating and improvement of the operating system and second the development of an effective remote job entry scheme to make it possible for users to submit jobs for processing at the Center from remote locations via standard telephone circuits. This latter service became operational during the spring from both the System/360, Model 20 and the IBM 1130. The Center has striven to make all of these changes in such a way that their visibility to users is minimized.

OTHER FACILITIES

During the year, significant progress was made by the Information Processing Services organization in assisting groups operating their own distinct computer facilities. In planning the development of these facilities in coordination with the establishment of goals for the Center, we hope to begin to provide a better-planned and more manageable computer resource for the Institute. Primary among these developments is the establishment of small computer installations around the campus to serve as remote job entry stations. Computers capable of serving in this role are currently located within the Departments of Civil Engineering, Mechanical Engineering, and Aeronautics and Astronautics, and in the Alfred P. Sloan School of Management, the Center for Advanced Engineering Study, and the M.I.T. Instrumentation Laboratory. To date, two of these facilities have started regular remote job entry operation with the Center. We expect that the remainder will do so in the near future.

As Dean Gordon S. Brown pointed out in the Report of the School of Engineering for 1966-67, the establishment of such a computer network foretells many benefits for the university community. It will promote an efficient use of limited resources and effective sharing of computer facilities and personnel.

PLANS FOR THE FUTURE

During the summer of 1968, the staff and the majority of the facilities of the Information Processing Services Center will be consolidated within the new building provided for the Center on the main campus. Subsequently, the set of services available through standard System/360 hardware and software technology will be expanded and improved. During the fall, we expect to implement more effective accounting routines for the System/360 installation so that we may bill users for various computer resources and other services in addition to central processor hours. The goal of this development is to bring the total charge to a user more
closely into line with the cost of that fraction of the total system resources which he commands. A broadly based accounting scheme similar to that planned for the System/360 has been in operation under CTSS on the 7094 for some time and, in fact, currently measures and charges users for a total of ten separate components of service.

During the summer of 1968, a third major category of service will be developed at the Center. This new service will provide users with access to an experimental machine, as distinguished from the current provision of throughput on a service machine. This new category of service will be provided by a System/360, Model 67 to be installed at the Institute in late July, 1968.

RICHARD G. MILLS

PROJECT INTREX

Project INTREX (INformation TRansfer Experiments) is now in its third year of operations under the general direction of Professor Carl F. J. Overhage. The dual purpose of the project is to perform research and experimentation directed toward the design of new library services that might become available at M.I.T. and elsewhere in the decade beginning in 1970, and to develop competence in the emerging field of information transfer engineering. To accomplish this broad purpose, a core program of four sets of experiments is planned, as follows:

1. Augmented-catalog experiments
2. Text-access experiments
3. Network integration experiments
4. Fact retrieval experiments

At present, the Electronic Systems Laboratory (E.S.L.), under its Director, Professor J. Francis Reintjes, is completing final preparations for conducting the augmented-catalog experiments and the text-access experiments. The network integration experiments and fact retrieval experiments will be undertaken when funds are available.

The research program to create and test an augmented, machine-stored, remotely accessible catalog of library holdings has been sponsored by the National Science Foundation for the last two years. The purpose of the augmented-catalog experiments is to determine — from actual library user response — the types of bibliographic data that should be included in a computer-stored remotely accessible catalog. To determine the most desirable set of entry points, a variety of data beyond those that are customary in conventional card catalogs has been selected for inclusion in the experimental catalog. The data that will be recom-
mended ultimately for inclusion in library catalogs depend on the results of experiments with actual library users.

Preparation of this catalog is going forward in three groups within E.S.L. — the catalog input group, the computer programming group, and the console group.

The catalog input group is responsible for preparing the experimental bibliographic data base. As of June 30, 1968, the group has completed cataloging 5,300 documents in selected areas of materials science and engineering. The initial experimental data base ultimately will contain 10,000 documents. In addition, the cataloging group has continually strived, and with a marked degree of success, to streamline the cataloging procedure.

The computer programming group is engaged in developing the storage and retrieval programs for the augmented catalog. The programs are being developed in three phases. Phase I is for use by the INTREX staff in testing and evaluating various techniques of storage and retrieval. Phases II and III are more advanced retrieval programs which will permit a broader scope of data base usage by the interested sector of the M.I.T. community. The Phase I programming has been completed and is being used to test how well certain of our file organization, storage, and retrieval techniques work. The Phase II system is in the final stages of debugging and should be available shortly for use by our community of users.

The console group is responsible for the design of an experimental augmented-catalog console. The user will employ the console, at the library or at a remote terminal, to query the catalog and to have displayed on demand selected portions of the catalog. The group has completed the specifications for the experimental console and is presently in the process of completing the fabrication of the console hardware. In addition, the display electronics and the digital logic for the console have been constructed and are currently undergoing tests.

The research program to create and test a text-access system has been sponsored by the Council on Library Resources, Inc., for the last year. The purpose of the text-access experiments is to evaluate schemes for giving a library user guaranteed rapid access to the full text of documents, whether he is at the library or at a location remote from the library. The first experimental scheme envisions a central store of full text on microfiche. The full text of the 10,000 documents itemized in the augmented catalog is now being placed on microfiche.

The microfiche will be stored and retrieved using a modified Houston-Fearless CARD retriever which is currently on order. Upon demand of the
user a selected microfiche will be located, transported, and then electronically scanned using a flying-spot scanner. The resulting electrical signals will be transmitted over a coaxial transmission line to the user's terminal, where the signal will be reconstituted into visual form.

Two terminals are presently being prepared for experimentation by the text-access group. One is a 35mm film station employing a high-resolution cathode-ray tube and a camera processor unit. The signal transmitted over the coaxial cable will be transformed on the face of the cathode-ray tube into a visible image of brief duration. A picture of this image will be taken with a 35mm camera. The film will be developed automatically in a rapid-processor specially modified for use with the INTREX terminal. The finished film then can be examined by the user on a conventional microfilm reader.

The second terminal will employ a cathode-ray storage tube. In this unit the transmitted signal will be converted to a visible image that remains on the face of the storage tube until it is electrically erased by the user. The quality of this image is marginal in our current experiments; we expect that it can be improved to yield a display that will be adequate for brief scanning. Thus the user will be able to check the relevancy of the document before requesting a permanent copy.

Other methods for providing transient displays or full-size permanent copies will be explored in later experiments; for the near term, we shall concentrate on the two schemes that have been outlined.

The Engineering Library, which is to provide the laboratory for carrying on the INTREX experiments, is being rebuilt. An area on the fourth floor (below the existing library) is now being renovated. When complete, this renovation will add approximately 4,500 square feet to the existing library. Rebuilding of existing book stack areas commenced in May, 1968, and work on the final construction phase is planned to start by October 1, 1968. It is anticipated that the new Engineering Library will be in operation in the spring of 1969.

CARL F. J. OVERHAGE
The following reports of our five departments and one research center differ appreciably in the fullness of detail with which their educational and research activities are summarized. Although Professor Hans-Lukas Teuber describes his review of current research in psychology as "extremely selective," it actually sets something of a record for thoroughness. His contribution is welcomed as a reflection of the enthusiasm and vigor that pervade the efforts of that relatively young department. From time to time, it is useful to have this kind of more extensive account that includes some actual research content.

By way of introducing the reports of the component units of the School, I shall limit myself to two types of commentary. The first concerns some current issues of educational policy that have schoolwide significance. The second is the annual feature of bringing up to date some standard quantitative measures of the School's growth, both as a whole and in its constituent parts.

**SOME EDUCATIONAL ISSUES**

To anticipate one point in the subsequent statistical summary, there has been a continued rapid increase in the number of our undergraduate majors. As Table III shows, our majors have doubled in five years — from 150 in 1962-63 to 305 in 1967-68. Furthermore, although there has been a persistent upward trend in all three relevant departments, the sharpest increases took place in Economics and Political Science between 1965 and 1967, and in Humanities this past year.

From the timing of these spurts, it is quite clear that they were related to changes in the character of our undergraduate programs.
Traditionally, these had been exclusively "double majors" in both a field of humanities or social science and a field of science or engineering. When economics and political science were separated into two departments in 1965, their undergraduate programs were also changed to single majors; and two years later the Department of Humanities, while maintaining its double majors, added the option of majoring exclusively in a humanities field. It should be appreciated that, even though the single majors either eliminated or at least greatly reduced the amount of required science or engineering in the junior or senior years, the numbers of free electives were increased sufficiently to allow any student to fashion a double major if he so chose. Furthermore, the General Institute Requirements, including 108 units of mathematics and science normally taken in the first two years, continue to apply to our students as they do to all others.

As may also be observed in other contexts, a measure of liberal reform frequently breeds the demand for more. As Professor Ithiel D. Pool mentions in his political science report below, there has been extensive agitation among the students in that Department for a marked reduction in the 108 units of mathematics and science that continue to be required. So far, students majoring in humanities or economics seem less concerned about this issue; but similar sentiments may well grow, or simply become more apparent, in those quarters as well.

This is a period when requirements of all kinds — not excluding those in the humanities and social sciences as applied to all M.I.T. undergraduates — are increasingly under attack. Indeed, it might be interesting to see how some experimental sample of students would react to a complete removal of requirements. In my own view, requirements have two legitimate purposes. The narrower is that the student may surprise himself by enjoying and profiting from an experience that he would not otherwise have elected. The more general is that requirements help to define an institution's purpose and thereby serve to attract only those candidates whose own aspirations are consonant.

Well short of the extreme position taken by a small minority, that M.I.T. should move toward adding a wholly coordinate liberal arts college with only the conventionally minimal science requirement, one can indeed argue persuasively for at least certain modifications in our present regulations. The most welcome would be a further movement, which happily seems quite likely, toward a greater variety of mathematics, science, engineering, and other technical subjects acceptable for satisfying the existing requirements. Nor should there be anything sacred about a minimum of 108 units of mathematics and science for every
last student, even though the very universality of that requirement does have a certain symbolic value.

In the course of this unfolding debate, it is well to keep in mind the positive advantages of the distinctive association that we have developed at M.I.T. between the humanities and social sciences on the one hand and the sciences and engineering on the other. For at least some of our disciplines, there are both kinships of method and complementarities of content that make the social scientist or humanist a better practitioner in his own field precisely because he has had substantial training also in the Institute's more traditional fields. I am convinced, moreover, that we turn out not only a distinctive professional product but in many respects a better one, because of our good fortune in being able to draw from a pool of candidates with scientific aptitude and interest.

Although it is by no means our sole purpose to push our undergraduates on to graduate work, it is at least symptomatic of the ability and seriousness of a department's students when a healthy proportion of them take that route. As one sidelight on this, I find interesting certain figures recently published by the National Academy of Sciences, *Doctorate Recipients from United States Universities, 1958-1966*. Of the recipients of U.S. doctoral degrees in economics in the period 1960-66, the number who had previously received their Bachelor's degrees from M.I.T. (21) compared very favorably with the numbers who had graduated from many large and distinguished liberal arts colleges, such as Princeton (19), Yale (26), Dartmouth (17), Brown (10), Pennsylvania (28), and Stanford (17). Although a Ph.D. recipient need not have majored in the same field as an undergraduate, it is still rather significant that so many M.I.T. undergraduates went on to the Ph.D. in economics, in comparison with the graduates of such colleges as these, where so many more students major in economics.

Incidentally, the corresponding numbers of M.I.T. baccalaureates who qualified for doctorates in certain comparable fields during the same period may also be of interest. In all, there were 22 in social sciences other than economics (ten in political science, eight in psychology, three in sociology, and one unspecified) — plus 13 in business administration and two in education. The corresponding figure for the arts and humanities was 11 (four in history, two in English and American literature, four in modern foreign literature, and one in philosophy).

It is well to mention briefly one other issue having to do with the number of units assigned to most undergraduate subjects in the humanities and social sciences; for, even though it may seem a rather petty
bookkeeping question, it may also provoke something of an argument next fall when our proposal reaches the Faculty.

In the early 1950's, when the Faculty approved the present pattern of eight required subjects in the humanities and social sciences for every undergraduate, it was symptomatic of the close bargaining on the question that each such subject was reduced to eight units from the customary nine—not, of course, by changing the three classroom hours per week, but by knocking an hour off the dubiously significant index of preparation time. This small indignity has been reluctantly accepted by the faculty of this School all these years because, until recently, it seemed to have little real importance.

The situation has now changed, however, because of our new pattern of single majors and the increased numbers of students in those programs. Since many of our subjects do the double duty of serving both as general education for all undergraduates and as departmental subjects for our majors, the latter are largely limited to a diet of eight-unit subjects within their own fields. Thus, when taking a sufficient number of subjects in any given term, the student must take at least six of them to reach the normal full-time registration of 45 units. This fate is all the more objectionable because, throughout the rest of the Institute, there has been a strong recent trend toward replacing the traditional nine-unit subjects with 12-unit ones.

Since the curriculum reform of the past few years has already changed all of the freshman and sophomore subjects in our area to nine units, the only further change needed is to do likewise for the junior and senior electives. This means, of course, that the required units of humanities and social science subjects in those two years would be increased from 32 to 36. Despite certain rumblings of resistance, we hope that the Faculty as a whole will accept this further step of "creeping humanism."

GROWTH STATISTICS
Since recent growth trends were rather fully discussed last year, attention will be concentrated here on just the developments of the past year.

Our total registrations in undergraduate subjects, as shown in Table I, again set a new record. The net increase of 813 over last year to a total of 12,251 represented about the same percentage increase as the year before.

As to our four disciplinary options in the sophomore year, history continues to increase significantly at the expense of literature and now enjoys the first-place position by a wide margin. Philosophy, in third place, also increased somewhat; and last-place social science about held its own.
Among the junior and senior electives, the social sciences have normally enjoyed a modest but distinct lead over the humanities, inclusive of foreign literature and the visual arts. This year, however, even though the social sciences increased their registrations from 3,433 to 3,650, the humanities expanded much more, from 3,222 to 3,810. Thus, from a peak of 53.8 per cent five years ago and 51.6 per cent last year, the social sciences now represent only 48.9 per cent of the registrations in this category.

Shifts in the relative popularity of the individual fields are best seen in Table II. As the most dramatic development, psychology has again taken over first place from economics, as it did previously in the two-year period 1963-65. Economics was also the only field that suffered an appreciable absolute decrease in registrations. There were no other changes of relative position among the first five places, although political science all but erased literature's lead for third place. The interdisciplinary subjects, philosophy, and visual arts all increased strongly enough to move ahead of music, even though the latter also enjoyed a moderate absolute increase. The same was true of foreign literature in relation to labor relations.

The recent increases in the numbers of undergraduate majors, as shown in Table III, were discussed earlier. As to our graduate students, almost all of whom are Ph.D. candidates, their numbers have been unusually static this year. The only notable change was a rather surprisingly large drop in linguistics, where a rather lean year for new admissions happened to coincide with a bumper crop of emerging doctors.

Tables IV and V show how undergraduates in the Institute's five Schools sort themselves out among the 11 elective fields of our junior and senior program of humanities and social sciences. The pattern, especially as focused in Table V, is not significantly different from last year's except in one or two respects. It is gratifying to see that the architects' understandable predilection for their own allied field of visual arts has been moderated somewhat, in favor of somewhat more elections of both humanities and social sciences. For the rest, the shift previously noted toward humanities and away from social sciences appears to be strongest in management and noticeable in both humanities and engineering. What shift there is in the choices of students in the School of Science is mostly toward foreign literature and visual arts.
### Table I Registration in Humanities, Languages, and Social Science

**Undergraduate Subjects 1967-68.**

<table>
<thead>
<tr>
<th>Program</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freshman program</strong></td>
<td>938¹</td>
<td>966¹</td>
</tr>
<tr>
<td><strong>Sophomore program</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>292²</td>
<td>219³</td>
</tr>
<tr>
<td>Philosophy</td>
<td>246</td>
<td>174</td>
</tr>
<tr>
<td>History</td>
<td>412³</td>
<td>336³</td>
</tr>
<tr>
<td>Social science</td>
<td>142</td>
<td>179</td>
</tr>
<tr>
<td>History</td>
<td>264</td>
<td>355</td>
</tr>
<tr>
<td>Philosophy</td>
<td>245</td>
<td>315</td>
</tr>
<tr>
<td>Literature</td>
<td>395</td>
<td>338</td>
</tr>
<tr>
<td>Music</td>
<td>228</td>
<td>300</td>
</tr>
<tr>
<td>Interdisciplinary</td>
<td>276</td>
<td>305</td>
</tr>
<tr>
<td><strong>Total humanities electives</strong></td>
<td>1,408</td>
<td>1,613</td>
</tr>
<tr>
<td>Economics</td>
<td>620⁴</td>
<td>729⁴</td>
</tr>
<tr>
<td>Political science</td>
<td>326</td>
<td>402</td>
</tr>
<tr>
<td>Labor relations</td>
<td>67</td>
<td>91</td>
</tr>
<tr>
<td>Psychology</td>
<td>642</td>
<td>773</td>
</tr>
<tr>
<td><strong>Total social science electives</strong></td>
<td>1,655</td>
<td>1,995</td>
</tr>
<tr>
<td>Foreign literature</td>
<td>132⁵</td>
<td>109⁶</td>
</tr>
<tr>
<td>Visual arts</td>
<td>240</td>
<td>308</td>
</tr>
<tr>
<td>Thesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>37</td>
<td>29</td>
</tr>
<tr>
<td>Political science</td>
<td>34</td>
<td>21</td>
</tr>
<tr>
<td>Course XXI</td>
<td>35</td>
<td>106</td>
</tr>
<tr>
<td>English composition</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Senior seminar (XXI)</td>
<td>32</td>
<td>—</td>
</tr>
<tr>
<td>Science writing</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>Elementary, intermediate, and advanced modern languages</td>
<td>290</td>
<td>343</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>5,917</td>
<td>6,334</td>
</tr>
</tbody>
</table>

1 Includes registration in special humanities subjects in French (24 in fall, 22 in spring) and in German (23 in spring).
2 Includes registration in comparable subjects in French (17 in spring) and in German (14 in fall).
3 Includes registration in comparable subjects in French (20 in fall) and in German (9 in spring).
4 Includes registration in Economic Principles I, 14.01 (fall, 275; and spring, 294).
5 Exclusive of 633 registrants in elementary, intermediate, and advanced languages.
6 Includes undergraduates in graduate linguistic subjects.
7 Taught by faculty of the School of Architecture and Planning.
### Table II  Percentage Distribution of Junior and Senior Electives in Humanities, Languages, and Social Science, by fields, 1961-68.*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychology</td>
<td>19.0</td>
<td>18.1</td>
<td>16.6</td>
<td>20.2</td>
<td>21.4</td>
<td>14.8</td>
<td>11.4</td>
</tr>
<tr>
<td>Economics</td>
<td>18.1</td>
<td>21.9</td>
<td>22.8</td>
<td>19.9</td>
<td>19.7</td>
<td>24.8</td>
<td>28.0</td>
</tr>
<tr>
<td>Literature</td>
<td>9.8</td>
<td>11.1</td>
<td>12.7</td>
<td>12.5</td>
<td>12.5</td>
<td>14.4</td>
<td>13.3</td>
</tr>
<tr>
<td>Political science</td>
<td>9.8</td>
<td>9.6</td>
<td>9.2</td>
<td>9.3</td>
<td>10.4</td>
<td>10.5</td>
<td>8.4</td>
</tr>
<tr>
<td>History</td>
<td>8.3</td>
<td>9.1</td>
<td>10.2</td>
<td>8.5</td>
<td>5.6</td>
<td>5.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Interdisciplinary subjects</td>
<td>7.8</td>
<td>5.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philosophy</td>
<td>7.5</td>
<td>6.9</td>
<td>9.3</td>
<td>9.1</td>
<td>13.2</td>
<td>12.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Visual arts¹</td>
<td>7.3</td>
<td>6.7</td>
<td>6.4</td>
<td>4.8</td>
<td>3.1</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Music</td>
<td>7.1</td>
<td>7.2</td>
<td>7.7</td>
<td>8.9</td>
<td>8.2</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Foreign literature²</td>
<td>3.2</td>
<td>1.9</td>
<td>2.7</td>
<td>4.3</td>
<td>3.5</td>
<td>4.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Labor relations</td>
<td>2.1</td>
<td>2.0</td>
<td>1.9</td>
<td>2.1</td>
<td>2.3</td>
<td>3.0</td>
<td>3.2</td>
</tr>
</tbody>
</table>


¹ Taught by faculty of the School of Architecture and Planning.

² Exclusive of elementary, intermediate and advanced language subjects; includes undergraduates in graduate linguistic subjects.
<table>
<thead>
<tr>
<th>Undergraduates</th>
<th>Graduates</th>
<th>Modern Languages</th>
<th>Total</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Science</td>
<td>Humanities</td>
<td>Total</td>
<td>Social Science</td>
<td>Humanities</td>
</tr>
<tr>
<td>1955–56¹</td>
<td>40</td>
<td>19</td>
<td>59</td>
<td>52</td>
</tr>
<tr>
<td>1956–57</td>
<td>38</td>
<td>32</td>
<td>70</td>
<td>69</td>
</tr>
<tr>
<td>1957–58</td>
<td>41</td>
<td>67</td>
<td>108</td>
<td>74</td>
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<tr>
<td>1958–59²</td>
<td>46</td>
<td>75</td>
<td>121</td>
<td>81</td>
</tr>
<tr>
<td>1959–60</td>
<td>38</td>
<td>64</td>
<td>102</td>
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<tr>
<td>1960–61</td>
<td>35</td>
<td>93</td>
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<td>1961–62³</td>
<td>55</td>
<td>88</td>
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<tr>
<td>1962–63⁴</td>
<td>65</td>
<td>85</td>
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<td>87</td>
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<td>1964–65⁵</td>
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<td>109</td>
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<td>Economics</td>
<td>Political Science</td>
<td>Psychology</td>
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<td>1965–66</td>
<td>50</td>
<td>60</td>
<td>114</td>
<td>224</td>
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<td>1967–68</td>
<td>81</td>
<td>76</td>
<td>148</td>
<td>305</td>
</tr>
</tbody>
</table>

* As registered in the second term of academic year 1955-56 to 1967-68 (omitting freshmen).
¹ Course XXI initiated.
² Graduate degree in political science initiated.
³ Special program in teacher training.
⁴ Graduate degree in linguistics initiated.
⁵ Graduate degree in psychology initiated.
⁶ Graduate degree in philosophy initiated, with small preregistration in 1963-64.
<table>
<thead>
<tr>
<th>School</th>
<th>Economics</th>
<th>Labor Relations</th>
<th>Political Science</th>
<th>Psychology</th>
<th>History</th>
<th>Subtotal in the Social Sciences</th>
<th>Literature</th>
<th>Music</th>
<th>Philosophy</th>
<th>Interdisciplinary Subjects</th>
<th>Visual Arts</th>
<th>Foreign Literature</th>
<th>Subtotal in the Humanities</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
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<td>42</td>
<td>90</td>
<td>10</td>
<td>34</td>
<td>4</td>
<td>13</td>
<td>6</td>
<td>150</td>
<td>2</td>
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<td>Engineering</td>
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<td>86</td>
<td>234</td>
<td>447</td>
<td>1,357</td>
<td>185</td>
<td>209</td>
<td>212</td>
<td>104</td>
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<td>66</td>
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<td>2,411</td>
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<td>Humanities</td>
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<td>298</td>
<td>176</td>
<td>755</td>
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<td>239</td>
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<td>Management</td>
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<td>53</td>
<td>158</td>
<td>30</td>
<td>24</td>
<td>29</td>
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<td>28</td>
<td>6</td>
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<td>99</td>
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<td>41</td>
<td>55</td>
<td>22</td>
<td>315</td>
<td>971</td>
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<td><strong>Totals</strong></td>
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<td><strong>158</strong></td>
<td><strong>728</strong></td>
<td><strong>1,415</strong></td>
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<td><strong>733</strong></td>
<td><strong>528</strong></td>
<td><strong>560</strong></td>
<td><strong>581</strong></td>
<td><strong>548</strong></td>
<td><strong>225</strong></td>
<td><strong>3,794</strong></td>
<td><strong>7,444</strong></td>
</tr>
</tbody>
</table>

1 This includes all students who have not yet made Course designations, plus a handful of unclassified graduate students.
Table V Relative Distribution of Registrants in Undergraduate Electives by Broad Fields and by Schools insofar as they can be identified, 1967-68

<table>
<thead>
<tr>
<th>School-Field</th>
<th>Visual Arts</th>
<th>Foreign Literature</th>
<th>Other Humanities</th>
<th>Social Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>.49</td>
<td>.01</td>
<td>.22</td>
<td>.29</td>
</tr>
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<td>Engineering</td>
<td>.06</td>
<td>.03</td>
<td>.35</td>
<td>.56</td>
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<td>.03</td>
<td>.49</td>
<td>.45</td>
</tr>
<tr>
<td>Management</td>
<td>.09</td>
<td>.02</td>
<td>.50</td>
<td>.40</td>
</tr>
<tr>
<td>Science</td>
<td>.06</td>
<td>.05</td>
<td>.53</td>
<td>.36</td>
</tr>
</tbody>
</table>

DEPARTMENT OF ECONOMICS

UNDERGRADUATE PROGRAM

The steady expansion in the number of undergraduate economics majors has enhanced the significance of the undergraduate curriculum reexamination undertaken by a committee chaired by Professor Duncan K. Foley. With a doubling in the last two years of the number of undergraduate majors and a doubling since last year of the Bachelor's degrees awarded, it has become necessary to consider more carefully the relationship of the undergraduate offerings to the program for economics majors and to the humanities and social science program elected by all undergraduates. As a result of the study by the Foley Committee, a number of modifications have been made in the undergraduate offerings. Their purpose is to achieve more cumulation and depth for economics majors and more homogeneity of student background in the subjects taken by majors and non-majors. At the present time, most of the junior and senior economics elective subjects, unless of a highly technical nature, are made available in the humanities program. As a consequence, they have as prerequisites only a year of Economic Principles, 14.01 and 14.02, and are necessarily less advanced than might be optimal for economics majors.

Under the new program, two new subjects in intermediate micro- and macro-economic theory have been added that will cover the theoretical subject matter of the present Prices and Production, 14.03, and Economic Fluctuations and Growth, 14.05, in greater depth. These new subjects in turn will be prerequisites for four existing junior and senior electives in Industrial Organization, 14.20; Monetary and Banking Policy, 14.40; Public Finance, 14.43; and International Trade, 14.54; as well as for the Economic Research Seminar, 14.39, and a new elec-
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tive, Econometrics, 14.31. The required subject in Statistical Method, 14.381, which is also a minimal graduate requirement, will have a special undergraduate section; and the Economic Research Seminar, required of all majors in their senior year, will be divided into several sections containing no more than a dozen students each. This latter change will make possible more interaction between student and teacher, closer supervision of a student’s research training, and a wider range of research-project subject matter. This seminar was conducted on a pass-fail basis as an experiment this year and, on balance, appears to have been an educational success. Finally, we have dropped the requirement of Information Systems, 1.00, and Differential Equations, 18.034, as science distribution subjects, but urge students to take work in computer techniques and mathematics beyond the freshman year. In the latter connection, we are giving thought to the development of a mathematics subject that is geared more closely to the particular needs of economists.

The humanities offerings have been modified in line with these changes. The four electives mentioned above with enhanced prerequisites have been removed from the list, and some of their subject matter has been included in the appropriate subjects, 14.03 and 14.05, which remain in the humanities program. We have added two more subjects, elective for both majors and non-majors, Economic History, 14.71, and Urban Economics, 14.51.

GRADUATE PROGRAM
The general examination for the doctorate was modified this year. Previously, the written and oral examinations were given in all fields over a two-week period at the end of the second year of graduate study. In order to reduce the pressure on students at that time, the written examinations in economic theory have been moved back to the end of the first year. Our experience is not yet sufficient to evaluate the change, but preliminary indications are that it is working satisfactorily.

The growing interest in urban economics and the addition of Professor Jerome Rothenberg to our faculty last year have permitted us to offer urban economics as a new doctorate field. Two graduate subjects are now given jointly in our Department and in City and Regional Planning. We have also rearranged the fields of econometrics and economic development. Econometrics has been separated into two basic subjects consisting of theory under Professor Franklin M. Fisher and applications under Professor Edwin Kuh, and a new seminar in advanced problems in the field is offered. More depth will be achieved in economic development by the addition of a subject in the theory of economic development.
under Professor Richard S. Eckaus and a new seminar under Professor Jagdish N. Bhagwati.

PERSONNEL CHANGES

Professor Michael M. Postan of Cambridge University returned again this year. Our new visitors consisted of Professors Heinz Lampert from the Technical University of Berlin, Maurice Levy-Leboyer from Caen University, Frederic Meyers from University of California at Los Angeles, James A. Mirrlees from Cambridge University, C. Christian von Weizsäcker from University of Heidelberg, and Professor Bhaskar K. Ghosh from Lehigh University. Professor Peter Temin transferred from the Sloan School to the Department in the field of American economic history. Professor Matthew D. Edel was appointed in the field of economic development. Next year, Professor Lester C. Thurow comes to us from Harvard University as a joint appointment with the Alfred P. Sloan School of Management. His work has been largely in the areas of the economics of human resources and poverty. The resignation of Professor Karl Shell to accept a position at the University of Pennsylvania was regretfully accepted.

On leave for full- or part-time this year were Professors Morris A. Adelman to accelerate his researches on the world petroleum market since World War II, Harold A. Freeman to continue research in statistical theory in the areas of experimental design and time series, Charles P. Kindleberger to teach at the five constituent colleges of the Atlanta University Center, Edwin Kuh to give full time to the development of time-shared computer programs in econometrics, Franco Modigliani to act as research consultant to the Bank of Italy, and Charles A. Myers to study labor problems associated with economic development and with the introduction of computers.

RESEARCH AND OTHER ACTIVITIES

This year a series of departmental working papers was initiated under the supervision of Professor Miguel Sidrauski as a means of communicating professionally in advance of journal publication—a process that is increasingly lengthening under the pressure of accelerated research output. Twenty-two papers were reproduced in this form this past year.

Several members of the Department were engaged in research in the field of economic development. Professor Everett E. Hagen focused on the interrelationships between economic and non-economic factors and published a volume entitled, The Economics of Development; Professor Eckhaus has been extending the linear programming models previously
DEPARTMENT OF ECONOMICS

developed for India to Chile; Professor Max F. Millikan, besides directing the Center for International Studies, was co-author of *No Easy Harvest: The Dilemma of Agriculture in Underdeveloped Countries* and co-editor of *The Global Partnership: International Agencies and Economic Development*; the investigation of development in Chile was initiated under Emeritus Professor Paul N. Rosenstein-Rodan; Professor Edel has been studying community development programs and the relationship of food supply to inflation; and Professor John R. Harris has published several papers on the role of entrepreneurship in developing countries.

A substantial amount of research has gone forward this year on the theory of economic growth, particularly with respect to the roles of fiscal and monetary policy. A large fraction of the Department has been actively participating — Professors Paul A. Samuelson, Fisher, Robert M. Solow, Peter A. Diamond and Shell, Pranab K. Bardhan, Foley, C. Duncan MacRae, and Sidrauski — and many papers have been produced in this group.

Professor Shell, aided by Professors Fisher and Foley, published a major study of the Education Opportunity Bank, a technique of borrowing for higher education with repayment made contingent upon future income.

Professor Rothenberg’s publications in urban economics included *The Economic Evaluation of Urban Renewal*, and Professor Kindleberger brought out the fourth edition of his important text, *International Economics*.

It is satisfying to observe the degree to which our Department gives of its time and advice to many government or quasi-government organizations. Only a listing can give an idea of the diversity of this involvement, ordinarily as consultants, unless otherwise noted: Professor Sidney S. Alexander — RAND; Professor E. Cary Brown — U.S. Treasury, Chairman of Advisory Committee on Research Development to the Social Security Administration, President’s Commission on Budget Concepts; Professor Robert W. Crandall — U.S. Department of Justice; Professor Evsey D. Domar — RAND, National Science Foundation; Professor Eckaus — Chairman of Research Advisory Committee on the New England Council; Professor Edel — Boston Model Cities Board, Pan American Union; Professor Fisher — Federal Power Commission, Federal Reserve Board; Professor Kindleberger — U.S. Senate Committee on Banking and Currency; Professor Millikan — Agency for Economic Development, Member of Committee for Development Planning of the United Nations, U.S. State Department; Professor Modigliani — Federal
A recent article in a national magazine decrying "the death of humanities" turns from the issue of student discontent to ask what can be done to recover vitality in the undergraduate liberal arts curricula. "The future may lie," the author suggests, "with those who are less encumbered by inherited structures and vanities" than with departments committed by habit to ordinary divisions of academic labor. The first of 12 examples, cited for their departures from tradition, was what the author calls "the unified humanities department at M.I.T."

The statement is worth mentioning here because it can be turned around to evoke several basic questions which confront this Department, and several inherent contradictions which have become more visible during the year under review. One of these, quite simply, is the matter of structure itself. To what extent is a unified humanities department compatible, as a faculty of disparate disciplines, with the fact of early specialization and professionalism in undergraduate education at M.I.T.? The second question has to do with intellectual style among individuals in such a faculty: Is the non-specialist, the young scholar-teacher, impatient with the limitations of existing disciplinary structures, more compatible with the spirit of the new experimental colleges than with a university strongly committed to advanced research and graduate
training? A third issue points toward Course XXI and the question of
the new Humanities major described below by Professor Roy Lamson),
by which a student may now concentrate, after his second year, ex-
clusively in one of the several fields of humanities. Here again we must
raise the question of compatibility. Which version of Course XXI ought
to be normative: that in which students combine humanities with engi-
neering or science, or that in which they do not?

The career of the Department during the past five years represents
compromises — both deliberate and accidental — on each issue. While
we continue formally to exist as a unified Department, the structure
of the faculty includes four separate sections, each with its own rights
to recommend appointment and tenure. While we continue to maintain
a program of interdisciplinary subjects in the core curriculum and more
recently in the upperclass program as well, we have also built a large-
scale series of electives determined wholly by the separate faculties of
each discipline. While the curriculum of the first two years is intended
for all students, the elective program must meet at once the interests,
needs and expectations of non-specialists, double-majors, and those who
concentrate in the new option of Course XXI.

These contradictions, probably unique to Humanities as a Depart-
ment at M.I.T., have grown more obvious during the past several years.
They are inherent in the multiple functions of the Department. They fol-
low with some inevitability from the extension of options in general edu-
cation and from the sheer increase of variety in what has been undertaken
in the freshman-sophomore program. They follow from the concurrent
effort to strengthen the quality of the undergraduate elective curriculum
and the graduate program in philosophy. And they proceed as well from
the fact that Course XXI is no longer one community of students, but five.

It must be said emphatically, however, that the more complex char-
acter of the Department ultimately represents a response to the remark-
able variations of intellectual taste, talent and interest which have
emerged among the students themselves. What will provide unity and
identity to this Department in the future will not and should not be a
matter of structure, ideology or personal style, but rather a common
concern for undergraduate curricula that necessarily serve a set of
different and varied purposes.

The Department of Humanities is and ought to be an experimental
college in its own right, since the traditions of the older liberal arts
colleges are not appropriate to it. While we must increasingly meet the
preprofessional needs of undergraduates who are preparing for graduate
study in the humanities, we must also continue to provide a coprofes-
sional curriculum for the majority of M.I.T. undergraduates whose careers will be in science or engineering.

During the spring term of 1968 four new options were developed for the freshman curriculum, and revisions begun on a fifth. Each of these subjects is directed toward a central theme, historically elaborated; and each is in some manner derived from a significant problem of contemporary concern: The Western Tradition, Identity and Autobiography, Language, Culture and Community, Conflict and Community in America, and God and Logic. Revisions are also to be made in the sophomore literature curriculum, and a third edition of the *Reader on Revolution* is being prepared (this time for publication) by Professors Arthur D. Kaledin and David B. Ralston. Funds for each of these efforts were provided by the Carnegie Grant of 1965, now in its final year. These funds have been the principal source — and an indispensable one — for the reconstruction of the entire core curriculum.

Carnegie funds were also used by the Department in June to sponsor the last of three national conferences at Endicott House on the Humanities curriculum in science and engineering education. In addition to faculty participants from ten other institutions this year, five undergraduates were invited to organize and direct a program of their own on student initiative in research, educational policy and curricular revision during the past year. The undergraduates represented California Institute of Technology, Carnegie-Mellon Institute, Case-Western Reserve University, M.I.T., and Newark College of Engineering. Professor Theodore Newcomb of the University of Michigan collaborated in another program organized by Professor Robert C. Davis of Case on the second day, which was largely concerned with recent studies of changes and attitudes among engineering undergraduates. Dr. Newcomb's report on student power was continued by Professor Jerome Y. Lettvin on the third day, when tentative plans were made for continuing the summer conferences in the future at other institutions.

The principal event sponsored by the Department of Humanities at Kresge Auditorium this year was a lecture-performance on October 27-28 by Mr. B. H. Haggin and members of the New York City Ballet, featuring Edward Villella and Patricia McBride in a production of the Stravinsky-Balanchine *Apollo*. The fall program also included performances by the Zagreb Pro-Arte String Quartet, the San Francisco Mime Troupe and Michael Lorimer. The Cherry Lane Theatre Group appeared in February for a performance of *In Circles*, a musical adaptation of works by Gertrude Stein, and four performances of *Riot* were given in April by the Theatre Workshop of Boston. More than 50 performances,
sponsored by the music faculty, are summarized below. The Humanities film series, associated largely with subject work, included 110 titles during the past year.

PERSONNEL

Walter F. Urbach, who came to the Department in 1935, retired this June as Associate Professor of Literature. A gracious and devoted teacher, he lent a quiet and steady compassion as friend and counselor to generations of M.I.T. students.

Professor E. Neal Hartley served this year as Acting Head of the History Section, Institute Archivist, and Secretary of the Faculty. He was a member of the Advisory Committee on Publication, the Committee on Educational Policy Task Force on the Reorganization of Faculty Committees, a member of the Board of Trustees of New England College, and the Board of Governors of the Concord Antiquarian Society.

Professor Louis Kampf's article on "The Scandal of Literary Scholarship" was published in the December issue of Harper's and in a longer version in The Dissenting Academy (Pantheon, 1968). He also published articles in The Nation and College English and lectured at the New Universities Conference in Chicago, the annual meeting of the College English Association, and the Canadian Council of Learned Societies.

Professor Roy Lamson served as Chairman of the Marshall Scholarship Committee. He is currently engaged in a biographical and critical study of Sir Philip Sidney.

Professor James F. Thomson published an article in The Journal of Symbolic Logic, "Proof of the Law of Infinite Conjunction Using the Perfect Disjunctive Normal Form." He represented the Department again on the Graduate School Policy Committee and was Visiting Professor during the summer of 1968 at The Australian National University in Canberra, where Judith Jarvis Thomson also taught.

Professor Cyril Stanley Smith continued to serve as a member of the Committee on Science and Public Policy of the National Academy of Sciences. During the spring term he was Visiting Fellow at St. Catherine's College, Oxford. He was also George Sarton Lecturer at the History of Science Society, and participated in the Symposium "Master Bronzes from the Classical World" at the Fogg Museum. In April, 1968, he was invited by the Government of Iran to participate in the Fifth International Congress on Art and Archaeology. His book, Sources for the History of the Science of Steel: 1532-1786, was published in May by the M.I.T. Press.

RICHARD M. DOUGLAS

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At the beginning of the spring term 1968, enrollment in Course XXI totaled 153, the highest registration in its ten-year history, and an increase of 36 students over the enrollment of the two previous years. Reasons for this increase possibly may be found in the initiation of XXI-B, Program 2, a new curriculum in 1966, which essentially provides, within the requirements for an M.I.T. degree, an opportunity for concentration in history, literature, philosophy, or music. Thirty-six students are now enrolled in this program (literature 18, history 8, philosophy 9, music 1). One may also look to the revisions and new offerings in the curricula in the history, literature, philosophy, and music sections of the Department, which in many ways have departed from the conventional academic patterns and have provided attractive and challenging approaches to humanistic study. An increase in the number of students registered for two simultaneous S.B. degrees in a five-year program is also evident.

The older Course XXI programs (XXI-A, Humanities and Engineering, and XXI-B, Program 1, Humanities and Science, with 117 students now enrolled) continue to offer combined studies which have prepared students for future work both in science and engineering and in the humanities, education, medicine, law, business, and Federal service. This year 26 seniors took degrees (XXI-A, 3; XXI-B, Program 1, 23); six deferred their degrees until September, and four were engaged in five-year double-degree programs.

Students have been admitted to medical schools and to major graduate schools in physics, mathematics, literature, history, and philosophy. It is interesting to note that this year's senior class includes three students in linguistics, two anthropologists, and one in Oriental studies, all of whom will do graduate work in their fields.

Information gathered for the July, 1967, Newsletter from Course XXI graduates demonstrates a wide variety of professional life, including physicists, mathematicians, biologists, doctors, lawyers (several in patent law), business executives, teachers of philosophy, history, political science, drama, literature; technical editors and program analysts; clinical psychologists, theologians, a publisher and editor of a major journal of psychology, a manager of the planning department of an oil company, a founder and leader of a baroque music ensemble, and a cellist in a symphony orchestra.
In a continued effort to bring together the student's educational experience at M.I.T., the Senior Seminar this year was devoted to problems of structure in the arts and in science. Visiting Professor Lancelot L. Whyte was joined by members of the staff of the Departments of Humanities, Modern Languages and Linguistics, Physics, Biology, and the Center for Advanced Visual Studies.

The senior theses have benefited from the greater attention of the various sections, which instituted thesis review committees. The range of student interest continues to be wide, and many seniors have clearly demonstrated superior ability to do independent research. The following titles may at least illustrate some of the subject matter: "Loyaulte Me Lie: A Study of Richard III Based on Sources Contemporary to Him"; "Crowds in Revolutionary Boston, 1763–1775"; "Friedrich Naumann and the Political Influence of Intellectuals in the German Reich, 1871–1916"; "Tension in Lolita"; "The American Dream: A Study of the Representative Works of Three Men — Fitzgerald, Steinbeck and Lewis"; "A Comparison of Bardo Yoga with the Upáya of Mandala Meditation"; "The Manly Femininity of Pao-Yu and Genji"; "Quantum Theory and Kant's Critique"; "Speculations on Artificial Intelligence: Its Nature and Possibility"; "Some Considerations of Explanation in Linguistic Theory and Psycholinguistics"; and "Cultural Developments Preceding the Appearance of the First Sumerian Cities."

Among the activities of the Course xxi Society, ably led by its student president, David N. Caplan '68, were two all-day faculty-student colloquia at Endicott House on "A Crisis in Physics" and "Social Roles for Academics." A joint program of poetry written and read by students and faculty complemented the Department's Poetry Reading Series.

Next year will give opportunity to seniors both for seminars in their chosen disciplines and an interdisciplinary seminar in the two major parts of Course xxi. The Course continues its experimentation in teaching the humanities in a "university with a primary focus on enlarging the horizons of science and the development of technology and its applications to our society."

ROY LAMSON

HISTORY SECTION

In the absence on sabbatical leave of its Chairman, Professor Bruce Mazlish, the section continued to work on further definition and development of its program in comparative modern history and of its curriculum.

A series of seminars provided lively stimulus to the former. Under the direction of Professor Robert E. MacMaster, in charge of activities
under the Ford Foundation grant of 1966, section members heard and discussed papers by Edmundo Flores of the University of Mexico on “Social, Economic and Political Aspects of Mexico’s Land Reform”; Jeffry Kaplow of Columbia on “The Poor in Eighteenth-Century France”; Franco Venturi of the University of Turin on “Current Soviet Historical Thought”; Theodore H. Von Laue of Washington University on “Reflections on Comparative Modernization”; William E. Griffith of the Department of Political Science on “Castroism and the New Left”; Melvin Lasky, editor of *Encounter*, on “Revolution and Utopia”; Rex Coleman of Harvard Law School on “Modernization and Law in Japan”; and Dan Avni-Segre of Bar Ilan University on “Israel: a Colonial Society in Transition.” Each was also attended by social scientists from other M.I.T. departments and by representatives of history faculties from neighboring institutions. Theodore H. von Laue and Dan Avni-Segre served with distinction, grace, and marked interest in the section’s general activities, Professor von Laue as Ford Visiting Professor of Comparative History. Two years’ experience has driven home the need to focus the seminars more sharply, all in a given year on a single large theme, for example, and to coordinate research activities, conceivably in a joint project, toward a goal of publications identifiable as tangible results of the section’s Ford grant efforts. Appropriate planning is in process.

Curriculum-building responsibilities in a context of growing enrollments and enlarged student interest in the discipline fell to a newly formed section curriculum committee (Professors Hartley, *ex officio*, Herzstein, Kaledin, MacMaster, Ralston, and Watt), subject to scrutiny in meetings of the whole section. Especially challenging was the need to strike the best possible balance, in the face of fiscal and pedagogical realities, among the general-education needs of the undergraduates, the demands of articulated and balanced programs for history concentrators in Course xxi, and the innovative possibilities of research and teaching in comparative modernization adopted by the section as its special focus. In the first area the section supported a new freshman core subject Conflict and Community in America, as likely from its concern with the real world to attract students to history earlier and eventually to require larger sharing by historians in its teaching. The section agreed to drop a number of upperclass electives to achieve continuing sound staffing of its sophomore subject and larger equity for younger staff members in opportunities to teach their own specialties. In the second, the special qualities of history at M.I.T. were defined, and representative programs presented for use by current and prospective history majors in the new
Course XXI-B, 2. The availability of courses at Wellesley through cross-registration and of offerings by the Departments of Economics and Political Science, joined to the section's own, promises well for their sound preparation. Finally, though deficiencies in command of foreign languages and of more traditional historical subject matter have suggested to some that the emphasis on comparative history and comparative modernization should fall mainly on research, with the more general "contemporary history" serving as special focus for the section's teaching efforts, the increasingly disciplined professional inquiry into the former, here and at other universities, and the special main strengths and concerns of the Institute seem to justify its even more vigorous prosecution. Two new appointments attest to the commitment: those of Robert M. Fogelson, an American urban historian, to this section, the Department of City and Regional Planning, and the Joint Center for Urban Studies; and of Robert I. Rotberg, an African specialist, to this section and the Department of Political Science, both in the rank of Associate Professor.

PERSONNEL

Professor Vladimir Dedijer was unable to come in either term as a Carnegie Visiting Professor. Assistant Professor David L. Schalk has resigned to accept a position at Mt. Holyoke College. Alfred Soman, Instructor in the spring term, will go to Carleton College. New appointments in addition to the above will bring J. L. Talmon of the Hebrew University as Ford Visiting Professor of Comparative History in the fall term and David H. Bell and Jane M. de Long as Instructors. Robert E. MacMaster was promoted to Professor and Arthur D. Kaledin to Associate Professor. Professors Diane S. Clemens and Martin Diskin will each be on leave for a term under a grant from the Old Dominion Foundation.

To mention but a few of many professional and civic activities of members of the Section, Professor Richard M. Douglas was elected to the Newton School Committee; Professor Thomas H. D. Mahoney continued to serve as a City Councilor in Cambridge; Professor Mazlish carried on research in London; Professor William B. Watson studied and lectured in Spain; Professor Clemens read a paper at the University of Moscow and helped to arrange a section-sponsored symposium on "The Russian Revolution: an Appraisal" in commemoration of its 50th anniversary; Professor Nathan Sivin studied and wrote in Japan; and Professor Arthur R. Steinberg divided his Old Dominion leave between scholarship and the Committee on Educational Policy. Professor Hart-
ley, still serving as Institute Archivist and Secretary of the Faculty, has had good reason to anticipate Professor Mazlish's return to duty.

E. NEAL HARTLEY

LITERATURE SECTION

During the past year much of the section’s energy went into transformation of the curriculum. Most of the electives offered were new and constituted an attempt to make the literary tradition relevant to the intellectual concerns of our students. Generally, the subjects purposely cut across the usual demarcations of genre and period ordinarily demanded by a literature curriculum. Where other areas of study proved useful in illuminating literary works, little hesitation was shown in using them. The section’s Curriculum Review Committee (which included a student representative) carried on a continuous dialogue on the nature of the curriculum and the success or failure of subject offerings.

Much of the Curriculum Committee’s time was spent in shaping the course of study of a literature major. The primary objective of the major is not to give the student preprofessional training, but to allow him to develop a program of studies which will be broadly humanistic. Students will plan their curriculum in consultation with their departmental advisors.

The section has also broadened its offerings in creative writing and has tried to make it an integral part of the curriculum. Similarly, we hope to build the making and criticism of film into more than an incidental adjunct to a literary education.

Finally, during most of the year the section showed great concern for fundamental educational issues. We hope to make this concern a part of the curriculum, both in subjects and in special seminars. Our feelings are that the kind of literary education we develop will determine the social place and relevance of literature itself.

PERSONNEL

Robert Adolph’s *Rise of Modern Prose Style* was published this spring by the M.I.T. Press. Professor Adolph has resigned to accept appointment at York University. Professor George J. Bornstein published articles in *Comparative Literature* and the *Keats-Shelley Journal*; he has received an Old Dominion Fellowship and will work in Ireland and England next year. Joseph S. Brown compiled an anthology on *Continental Literature* published by J. D. Lippincott Company. Michael B. Folsom published *The Mysterious Grain: Science in Search of the Origin of Corn* (New York, 1967), a review article in *The Nation*, and a chap-

**LOUIS KAMPF**

**MUSIC SECTION**

During the current academic year Dr. Fritz Winckel joined the music section faculty as Visiting Professor. Dr. Winckel is Director of the Institute of Experimental Music at the Technische Universität Berlin. He presented lectures on electronic music, structural comparison of music and speech, psycho-acoustic problems in recent music, composition and performance of experimental music. Professor Winckel also arranged and directed a concert of experimental music.

In December the music section and the Department of Physics presented a joint colloquium on “The New Family of Strings.”

Professor Klaus Liepmann conducted the M.I.T. Choral Society and 63 members of the Boston Symphony Orchestra in performances of Bruckner's *Mass in E Minor*, Stravinsky's *Symphony of Psalms* and Bartok's *Cantata Profana* (first performance in the Boston area). The M.I.T. Glee Club, combined with the Mount Holyoke and Sarah Lawrence Glee Clubs, performed under his direction Orff's *Carmina Burana*
and Honegger's *King David*. The Christmas concert of the Choral Society reconstructed a typical Christmas Festival of Bach's time by presenting two Christmas cantatas and the *Magnificat*. The topic of Professor Liepmann's Harvard Extension Course was the music of Joseph Haydn. He was invited by the Rockefeller University to participate in a colloquium on science and the arts.

Professor Gregory Tucker coordinated the Humanities Series and Chamber Music at M.I.T. series and also performed in one of the chamber music concerts with violinist Eric Rosenblith. He performed at the Gardner Museum in Boston with flutist Karl Kraber. At Wellesley College he and John Buttrick, assisted by percussionists from the Boston Symphony Orchestra, played Bartok's *Sonata for Two Pianos and Percussion* and Stravinsky's *Sonata for Two Pianos*.

Professor David Epstein received his Ph.D. in Musical Theory and Composition from Princeton University.

John Cook composed incidental music for *The Prime of Miss Jean Brodie*, which is having a successful run on Broadway. He also conducted a performance of the *St. Matthew Passion* by Bach at the Church of the Advent in Boston, where he is organist and choirmaster.

John Buttrick performed concerti of Mozart, Beethoven and Schumann in New York City and in other cities. At M.I.T. and in the Gardner Museum he gave solo recitals and performed with Louis Moyse music for four-hand piano by Schubert. He is currently preparing for a tour of Switzerland, Holland, and Germany in November.

Professor Allen Forte resigned in order to accept an offer from Yale University to head its Music Theory Department.

Robert S. Freeman will join the faculty of the music section in the fall as Assistant Professor of Music. Professor Freeman is a graduate of Harvard University (A.B. 1957) and Princeton (M.F.A. 1960 and Ph.D. 1967).

**KLAUS LIEPMANN**

**PHILOSOPHY SECTION**

**UNDERGRADUATE STUDIES**

The emergence of new varieties of Course XXI and the resulting possibility of undergraduate majors in philosophy dictated a new look at the structure of undergraduate electives. Accordingly, a subcommittee met continuously throughout the fall term and made proposals to the section, which were accepted. These lay down basic subjects which should be available each year, and more advanced subjects which should be available at least once in every two years. A third group of subjects will be
DEPARTMENT OF HUMANITIES

primarily for graduate students but open to suitably qualified undergraduates. Our intention is thus to provide a well-rounded curriculum which will enable a Course XXI student to become acquainted with the major trends and fields in philosophy and also provide suitable preparation for those who wish to go on to graduate work.

For students whose main work lies outside the humanities, our policy remains that of providing as diversified and nourishing a range of diets as we can. Though many such students are interested in philosophy of the various sciences, not all are; some wish to study ethics, some political philosophy, and some philosophy of religion. The new arrangement should help these too.

GRADUATE STUDIES

It is expected that three students will be on the degree list this September. The section continues to place its graduate students well. Four have accepted appointments for 1968-69; at Yale University, Brown University, Indiana University and Hunter College.

An increasingly difficult problem is that of attracting new students. It is gratifying that only students of high caliber apply, but it is disappointing that too many of these elect to go to Harvard, Cornell, Princeton, or Rockefeller. The reasons for this are not entirely clear to us, but there is suspicion that our financial awards are not sufficiently competitive.

PERSONNEL

Professor Huston C. Smith was named by Phi Beta Kappa as one of its Visiting Scholars for 1967-68, thereby becoming the first M.I.T. faculty member to receive this honor. His duties took him to eight colleges and universities, ranging from North Carolina to Minnesota; at each he took part in classroom and seminar discussions, met informally with students and faculty, and gave one address open to the entire academic community.

Professor Gerald B. Dworkin spent this year at Harvard Law School on a special fellowship available to scholars who wish to know about jurisprudence but not to become professional lawyers.

Professor Mark A. Levensky was on Old Dominion leave during the spring term.

John C. Graves was honored with an Everett Moore Baker Award for outstanding undergraduate teaching.

Keith Donnellan of Cornell University was Visiting Professor for the spring term. He gave classes on theory of knowledge and naming and referring.
Section members continued to be in remarkable demand to give lectures and read papers at other institutions. Indeed, four members made among them 24 visits, covering 14 states and one Canadian province.

Next year we lose the services of Professor Abner E. Shimony, who goes to Boston University to take up a joint appointment in physics and philosophy. Professor Hubert L. Dreyfus also leaves us to take up an appointment at Berkeley.

JAMES F. THOMSON

DEPARTMENT OF MODERN LANGUAGES AND LINGUISTICS

GRADUATE PROGRAM IN LINGUISTICS

In November, 1967, Professor Noam A. Chomsky received an honorary doctorate of Literature from the University of London.

Dr. J. Frits Staal of the University of Amsterdam, a specialist in Indic philology, is completing a one-year appointment as Visiting Professor of Linguistics. During the first term he taught Introduction to Sanskrit, during the second The Pāṇinian Tradition in Linguistics.

Professor Edward S. Klima resigned at the end of 1967 to accept a position at the University of California at San Diego.

A book by Professors Chomsky and Morris Halle, entitled Sound Pattern of English, was recently published by Harper and Row, Publishers.

Professor Chomsky is preparing studies in syntax and semantics. Professor Halle is composing a handbook of phonetics and pursuing research on the history of the English stress system and on problems of markedness in phonology. Professor G. Hubert Matthews is at work on a number of projects, among them the following: a monograph on the phonological development of Crow and Hidatsa, a textbook on the algebraic properties of grammars of natural languages and language-like systems, a monograph on analysis by synthesis with respect to natural languages and its application to automatic translation and information retrieval, and a contrastive analysis of French and English syntax and usage as research toward a computer program for translating from either of these languages to the other. Professor Kenneth L. Hale is doing research on the grammar of Walbiri of Central Australia, the grammar of Navaho, comparative Uto-Aztecan, and change in case and voice systems. Professor René P. V. Kiparsky will be on leave in 1968-69, and plans to spend part of the year in India, where he will continue his studies in Indian
linguistic theory and in Sanskrit grammar. Professor John R. Ross is preparing a book on abstract syntax in collaboration with George Lakoff, and is working on the problem of the relationship between syntax and semantics.

**GRADUATE PROGRAM IN LANGUAGES**

For many years the Department has offered one-term subjects in Scientific French, German, and Russian to prepare doctoral candidates for reading examinations in their fields of specialization. This year, for the first time, it has offered two-term subjects (4-0-8 units per term) on a pass-fail basis in Intensive French, German, Russian, and Spanish for doctoral candidates who wish to attain intermediate competence in speaking as well as in reading. A total of 63 students fulfilled the foreign language requirement for the degree by passing these two-term subjects: in French, 20; in German, 25; in Russian, 12; in Spanish, 6. The motivation was very high, and the attrition accordingly slight.

On February 6, 1968, Associate Dean of the Graduate School SANborn C. Brown sent a letter to all members of the Faculty in connection with the doctoral foreign language requirement, asking how they felt about it in view of the national trend toward reduction or elimination of such requirements. A clear majority of the respondents stated that the Institute-wide regulations now in force are inappropriate and that each department should be free to make its own decisions in the matter.

At its 1968 meeting the Visiting Committee for Modern Languages and Linguistics agreed to recommend that the one-term subjects in Scientific French, German, and Russian be eliminated because of their inadequacy and replaced by two-term subjects.

**UNDERGRADUATE PROGRAM IN LITERATURE AND LANGUAGES**

Three books by members of the foreign literature staff appeared during the spring term. Professor William F. Bottiglia is the editor and co-author of *Voltaire: A Collection of Critical Essays* (Twentieth Century Views), published by Prentice-Hall. Professor Krystyna Pomorska is the author of a volume entitled *Russian Formalist Theory and Its Poetic Ambiance*, published by Mouton (The Hague and Paris). Professor Robert E. Jones’s book, *Panorama de la Nouvelle Critique en France*, has just appeared in Paris (publisher: Centre de Documentation Universitaire), and in due course will appear on this side of the Atlantic in an English version. Professor Martin Dyck, whose major study on Schiller’s poetry, *Die Gedichte Schillers*, was published in 1967, is now preparing a series of articles on Schiller’s metaphoric imagination and is also doing research on relativity in physics and in fiction.
The French literature program has been expanded from four to six subjects. Starting in the fall of 1968, they will be offered in the following rotation: Contemporary French Drama, French Romanticism, French Prose Fiction, Seminar in French Literature, Classical French Drama, Modern French Poetry.

In the fall of 1967 a questionnaire composed by David N. Ilfeld, a senior majoring in physics and an associate of the Student Committee on Educational Policy, was distributed to all undergraduates then enrolled in foreign language and literature subjects. Its purpose was to determine how much interest there is at the Institute in a Course XXIII major. The key questions asked were these: (1) If a foreign literature major were to be offered, would you be interested, and if so, in what language? (2) If a double major in a modern foreign literature and science or engineering were to be offered (parallel to that in Course XXI), would you want to take it? (3) Would you want to take an interdisciplinary major combining the study of a modern foreign literature with the history and culture of the country involved (for example, the literature, the history, and the art of France)? If so, in what language?

In his report on the results of this questionnaire, Mr. Ilfeld comments as follows on the responses to these questions: “Out of 314 students, 129 students indicated they would be interested in taking a foreign literature major, a double major, or an interdisciplinary major. Ten people out of this 41 per cent responded affirmatively to all three options, while many students said yes to only one option. The three options are frequently (from the students’ point of view) mutually exclusive, which indicates the need for a large degree of flexibility in any proposed program.”

The departmental Visiting Committee, after studying this report and discussing its implications with the administration and the foreign literature teaching staff, decided to recommend that a Course XXIII major in French, German, and Russian, comparable to that in Course XXI, be introduced.

HUMANITIES IN FOREIGN LANGUAGES

The third-term offering in the Humanities in French program, a history subject focused on the twentieth century, has proved to be unsatisfactory for a number of reasons. Subjects in contemporary history tend to deteriorate into a series of bull sessions on current events. They make a proper perspective very difficult, if not indeed impossible. They deal with material still in the making, and accordingly not yet amenable to objective scholarly treatment. They expose the instructor, whether
justly or unjustly, to the charge that he is abusing his position to propagandize his personal opinions on topical issues instead of maintaining a genuinely humanistic attitude of liberal sympathy toward the various points of view.

By common consent of those who have taught this subject and those who have taken it, the focus will be shifted back next fall to the French Enlightenment. Fortunately, this period includes all of the basic ideas and issues of modern times, which can therefore be studied in their first or earlier forms and meaningfully related to later developments with the aid of solid scholarly works affording an intelligent perspective on current history.

WILLIAM F. BOTTIGLIA

DEPARTMENT OF POLITICAL SCIENCE

Curricular reform and urban affairs have been the outstanding preoccupations of the Department during the past year.

CURRICULUM REFORM

It has often been argued that the only good curriculum is one in the process of reorganization. There are many good education programs, but any of them becomes ineffectual if it becomes routine. The excitement of developing something new, the intellectual stimulus of thinking through once more the content of what is taught, is probably more important than the character of the solution in producing effective teaching.

As noted in last year's report, the Department decided, after a decade, that the time had come for reevaluation. We already had an excellent graduate curriculum. In the American Council on Education Survey of American Universities, the special panel of political science experts rated this Department as tied for second place with Harvard in effectiveness of graduate instruction.

Nonetheless, the Department felt that the time had come for rethinking, particularly of the undergraduate curriculum, but also of the graduate one. A committee was set up a year ago, chaired by Professor Donald L. M. Blackmer. It made its report in the fall. Discussions were conducted among the faculty and among the student body during the year; decisions were made and implementation begun this spring. The Department has requested Professor Blackmer to head a continuing educational policy review process. We review here in condensed form some of the major changes made.
GRADUATE PROGRAM

ADVISORY BOARDS

Each student now has a three-man Advisory Board with which he meets for about an hour at least once a term to map out his subject selection and to discuss any problems he may have. Once the student has passed his General Examination and is working on his dissertation, his advisors are his dissertation committee, but until then he is assigned to a Board. The Boards are mixed rather than specialized. Previously, the advising of pre-thesis students was largely done by the two graduate registration officers on registration day. A check that all requirements were met plus a quick interchange about any problems was all that was possible. The new system provides much deeper guidance for each student by a cross-section of the department faculty. Formal requirements have been relaxed somewhat by dropping the requirement for a minor, since the Advisory Board will assure itself of the breadth and coherence of the student’s over-all program.

FIELD STRUCTURE FOR THE GENERAL EXAM

The General Examination covers four fields as it has in the past. Now, however, there will be one required field—political analysis—and the other three may be selected from a much enlarged list. The original requirement had been four fields out of the following six: comparative government, international relations, defense studies, political development, communications and political behavior, and science and public policy. To this list we have added political analysis, urban studies, political theory, methodology, and area fields, such as Europe, Southeast Asia, India, and the Middle East. Fields outside political science continue to be accepted and encouraged. The student’s Advisory Board must satisfy itself that the four chosen fields plus other study constitute a sufficiently comprehensive coverage of the discipline.

THE FIELD OF POLITICAL ANALYSIS — AND COURSETTES

Teaching in this Department has always been linked closely to research. From the beginning of our graduate program we have had the view that the best professional education is apprenticeship in actual research. We have had a requirement, which we retain, that before undertaking dissertation research the student must work on some research project under the supervision of a faculty member. Many students meet this requirement in the course of research assistantships. Those who do not need financial support or have fellowships that preclude working may meet the requirements through research seminars, summer work, or in other ways.
DEPARTMENT OF POLITICAL SCIENCE

Nonetheless, we felt that our formal training in the basic methods and philosophy of social research needed strengthening. To that end we have put together a set of subjects to constitute a core to our curriculum and have designated that field "political analysis." We identified five areas of training: (1) mathematics and statistics, (2) philosophy of social science, (3) research methods, (4) computer programming, and (5) political and social theory.

We faced the familiar problem in all disciplines—that what a scholar needs to know grows far more rapidly than what any human being can encompass. Furthermore, students come to us with varied preparation in the above five areas. To permit students to tailor the equivalent of three to five subjects into a package that fills their individual needs was the challenge we faced.

To provide adequate coverage for all students we have added and will add several new subjects, such as that of Professor Hayward R. Alker in Multivariate Analysis, a subject by Stuart D. McIntosh and David M. Griffel on the ADMINS System, and an additional subject in Political Theory by Professor Paul Kecskemeti. To gain the necessary flexibility for students with different needs we have broken many of these subjects into half-subjects and third-subjects which we nickname "coursettes." Examples are Dr. Richard Maisel's subject on Survey Analysis, both Professor Ithiel D. Pool's and Professor Kecskemeti's subjects in Political Theory, the ADMINS subject in basic computer programming, which is a self-teaching subject developed by Professor Joseph Weizenbaum, and hopefully an increasing number of other subjects. Various devices are being used, such as breaking a full subject into parts, meeting alternate weeks, designating one session a week only for those who wish certain more intense materials. Time alone will tell whether the complications are excessive.

UNDERGRADUATE PROGRAM

INCREASED FLEXIBILITY

The Department has dropped some previous requirements for the S.B. Twenty-four hours of natural science beyond the basic Institute requirements had been demanded by the Department. A number of undergraduates in this Course had protested this requirement and, indeed, the general Institute requirements too. They argued that they had made a deliberate choice to move out of the natural sciences and that they were being compelled to take subjects of less professional and intellectual significance than they would elect freely. They circulated petitions. These
raised a fundamental question regarding which there is merit on both sides. On the one hand, it is clear that M.I.T. is not a general university and that the people it turns out, even those in the social sciences, ought to have a deep grounding in natural science. We have an opportunity to turn out a very valuable and rare product; namely, the social science analyst with the technical competence necessary to address himself to the problems that arise from the application of technology to society. At the time of admission the students who come to us have shown the talents and inclinations qualifying them for that combination of training. On the other hand, some small percentage of the students who start their freshman year intending to be natural scientists or engineers do poorly, become disenchanted, rebel against their intended discipline, and want no more to do with it. They demand freedom from science requirements and question whether they should be forced to transfer to another institution to do what they wish to do.

There is no clearly right answer to this controversy. The faculty of the Department is not of one mind any more than is the student body, nor the Faculty of the Institute as a whole. The problem is to hit a fair level of requirements to assure the student some literacy in the natural sciences, as in other fields, while not indefinitely forcing a student into a mold that he consciously rejects.

The Department has not requested any change in general Institute requirements. On the other hand, the Department has decided to drop the natural science requirements that go beyond what the Institute requires of all students. The Department has also dropped any specification of science elective subjects.

A SOCIAL SCIENCE LABORATORY

Among the Institute’s General Requirements is one 12-hour laboratory subject. Both students in this Department and faculty members from many departments have suggested that there should be laboratory options offered in social science fields. The Department has agreed and will be developing one.

RECOMMENDATIONS TO THE COMMITTEE ON EDUCATIONAL POLICY

In addition to what the Department could do on its own authority, it has made some recommendations to the Committee on Educational Policy (C.E.P.) concerning the listing of our subjects at nine hours instead of eight and the counting of certain subjects outside the Schools of Science and Engineering, such as Experimental Psychology, as science subjects. The C.E.P. has our recommendations under advisement.
The introductory social science subject, Society and Man, 17.01, which has been growing steadily, is also due for review and revision. Professor Roy E. Feldman will be taking over direction of this subject from Professor Pool.

In addition to these formal changes in curriculum we should note a number of informal pedagogical experiments and also some subjects that fall outside the usual academic pattern. Two freshman seminars were offered, one by Dr. Rosemarie S. Rogers, who has a background in linguistics as well as in political science, on Language and Politics, and one by Professors John S. Saloma and G. Eric Hansen on Vietnam. Team teaching of joint subjects was done by Professors Willard R. Johnson and Frank Bonilla on Revolutionary Ideologies, by Professors Daniel Lerner and William E. Griffith on European Politics, and by Professors Lucian W. Pye and A. Doak Barnett on East Asia. A political-military game was conducted by Professor Lincoln P. Bloomfield's students. A laboratory with experimentation was introduced into his subject in Political Psychology by Professor Feldman. A self-teaching programmed subject in Computer Programming was developed by Professor Weizenbaum and Professor Robert R. Fenichel of the Department of Electrical Engineering.

Professor Frank C. Colcord taught once more the joint Dartmouth/M.I.T. triple subject on urban problems, for which Dartmouth students come to live in the Boston area for a term. He also taught a subject at the Kennedy Institute at Harvard University on Cambridge Model Cities Planning. Professor William W. Kaufmann directed the Systems Analysis Program sponsored jointly by the Department of Political Science and the Center for Advanced Engineering Study. That program enrolled 13 mid-career students from 11 departments of the Federal government for a year of study designed to enable them to apply the newer techniques of program budgeting. Professor Norman J. Padelford of this Department taught a subject on Public Policy and the Use of the Sea in the Department of Naval Architecture and Marine Engineering. Under a National Sea Grant Curriculum Development Project he is preparing a casebook on law and policy for the seas.

**URBAN STUDIES**

Before Professor Robert C. Wood went on leave of absence two and a half years ago to be Under Secretary of the newly formed Department of Housing and Urban Development, he and Professor Colcord represented our total strength in the field of urban studies. In substituting for Professor Wood, we assumed that urban studies would become so central
to the nation and to the university in the years to come that we should seek to increase our strength permanently and not make short-term replacements pending his return. Thanks to the Ford Urban Grant, that policy has been justified. We now have a large and outstanding faculty fully or partially committed to urban problems. The main foci of this Department’s work on urban politics have fallen into three fields: ghetto problems, transportation, and urban information systems.

Professor Alan A. Altshuler is working on the politics of transportation and urban planning. He has taught a subject in urban problems jointly with Professor Bernard J. Frieden of the Department of City and Regional Planning. He is continuing work on a book on the Federal government and urban transportation. He prepared two papers for the Department of Housing and Urban Development, one on “The Role of Transit in Metropolitan Life” and one on “Requisites for a Revival of Urban Transit.” He and Matthew A. Crenson worked on the General Motors Traffic Safety Project and its summer study on the political dimensions of a dual-mode highway system.

Professor Leonard J. Fein has been appointed Associate Director of the Harvard-M.I.T. Joint Center for Urban Studies. His specific responsibility is with the Joint Center’s research program. Among the new activities of the Joint Center will be a Boston Area Survey that will provide our students with an opportunity at least once a year to participate in the design of a field survey and in the collection and analysis of field data. Professor Fein has been very active in the study of urban ghetto problems and in related public programs, such as M.I.T.’s Science Day Camp. He initiated and has been in charge of our training fellowships for the study of urban society, funded by the National Institute of Mental Health in a grant jointly to the Departments of Political Science and City and Regional Planning.

Professor Johnson is taking a leave of absence for the fall term in consequence of his newly assumed duties as President of Circle Associates, Inc., a company formed in Roxbury to undertake a program of business research and development, particularly in the construction field, in the black ghetto. He is a member of the Board of Directors of the Boston Urban League. He participated in the launching of the Unity Bank.

Professors Harold R. Isaacs and Bonilla also have an active interest in ghetto problems. Professor Isaacs has been an Associate Fellow of the Metropolitan Applied Research Center in New York, headed by Dr. Kenneth Clark. Professor Bonilla presented the opening and closing reports of the National Conference on the Special Educational Needs of Urban Puerto Rican Children, sponsored by the U.S. Office of Education,
and presented a paper on “Social Science and Urban Policy” at the Center for Interdisciplinary Study of Urban Problems in Jahuel, Chile.

Professor Colcord continues his comparative study of the making of transit policy in American cities. That study has been supported partly by the General Motors Traffic Safety Project and now by the Urban Systems Laboratory. He received a grant from the Humble Oil & Refining Co. to serve during the summer of 1968 as social scientist in residence in their project on “The Businessman and the Ghetto.”

Professor Harvey M. Sapolsky continues his work on the provision of scientific advice to state and local governments, on which he published an article in Science. He and Professor Feldman are also working with the General Motors Traffic Safety Project on the social and economic correlates of bad driving habits. Professor Feldman is doing some research under Urban Systems Laboratory auspices on motivating educational achievement among deprived children. He is in the core group of the 1968 summer study on urban information systems.

Professor John F. Collins, the former Mayor of Boston, is jointly a member of three departments, of which Political Science is one. He has participated in the Institute’s urban planning group and in implementing the Urban Fellows program.

Visiting Lecturer O. Eugene Dial came here from the chairmanship of the Political Science Department at Idaho State University to develop a program of relations between the Institute and the city in the area of information systems. He has conducted a review of the state of the art of urban information systems for a task force of the National Academy of Science’s National Research Council. He is participating, along with Professors Pool and Weizenbaum, and Mr. McIntosh, in the Joint Center’s Boston Health Information System Project. He is working with the Boston Model Cities Board on their information systems needs and serving as liaison between the Urban Systems Laboratory and the Boston Model Cities program. He has been codirector of the information systems panel of this Institute’s urban summer study.

Professor Pool, Stuart McIntosh, and David Griffel have been working on the general problem of information systems. They have developed the ADMINS system for file management and data analysis. They have been devoting increasing attention to the extension of such a system in the direction of an information utility for purposes such as urban information systems.

Professor Pool is also serving as an Associate Director of the Urban Systems Laboratory. Among the members of the Department who are
affiliated with Urban Systems Laboratory projects are Professors Dial, Colcord, Feldman, Sapolsky, and Lerner.

RESEARCH FACILITIES

The Center for International Studies, the Joint Center for Urban Studies and now the Urban Systems Laboratory are the organizations with which most research in this Department is affiliated. About three years ago the Department established a data archive mostly consisting of about 2,000 public opinion surveys from around the world, borrowed from the Roper Public Opinion Research Center, of whose International Survey Library Association we are members. This spring we have structured that archive in a Bureau of Social Science Information under the direction of Stuart McIntosh, with David Griffel as Associate Director, and a faculty Executive Committee. The Bureau provides service in the use of the archive and in the use of the ADMINS system, which is the operating system for the Bureau. Instruction in ADMINS will be given. Additional consoles linked to the CTSS (computer time-sharing system), the host system for ADMINS, are being installed so as to accommodate the increasing load of on-line interactive data analysis both in research and in classes. That Bureau plus the establishment of the Boston Area Survey described above should provide an excellent environment for students and faculty interested in survey research.

One of the unusual features of political science at M.I.T. is the extent of research which is interdisciplinary between social and natural sciences. The students and faculty of this Department are extensively engaged in studies of social aspects of technological developments. As already noted, a study of traffic safety involves Professors Altshuler, Sapolsky, Feldman, and Colcord together with civil engineers and others. A Sea Grant project on curriculum development concerning law and policy on the sea for the Department of Naval Architecture and Marine Engineering involves Professor Padelford. A systems analysis curriculum is being offered jointly with the Center for Advanced Engineering Study. In addition, a history of the Polaris Program is being conducted through the Instrumentation Laboratory by Professor Sapolsky.

Attention should also be drawn to varied activities in the area of computer applications by Professors Weizenbaum (who has a joint appointment in Political Science and Electrical Engineering), and Pool, along with Stuart McIntosh, David Griffel, and others.

OTHER DEPARTMENTAL DEVELOPMENTS

For the first time a realistic expense budget has been given to the Department. This positive measure should permit a tightening up of budget-
Space continues to be a pressing problem. The Institute is providing us with two additional offices by splitting a conference room. After this year the situation will become desperate.

Applications for admission to this Department have continued to grow. We now have 76 undergraduate majors (compared to 73 last spring) and granted 26 S.B. degrees. We received 215 applications for graduate study, of which we admitted 22 in the expectation of having a class of about 18. No admission quotas were increased this year. This will present a problem for the future, since our National Institute of Mental Health Grant for training in urban politics was conditioned on growth in our student body as a means to increase the number of urbanists. We were able to make the increase within our quota this year, but will need reconsideration of the quota next year. We granted 14 doctorates and three Master's degrees this year.

Persons trained in our graduate program have now been appointed to teach at Harvard, Yale, Chicago, Columbia, Berkeley, Michigan, Michigan State, the Hebrew University, Pennsylvania, U.C.L.A., Minnesota, and many other distinguished institutions.

Perhaps the most serious problem on the horizon is the drying up of fellowship funds, particularly for international studies. The Ford Foundation's decision to pull out of the Woodrow Wilson Fellowship program and concentrate its support of graduate education in ten universities was a serious blow to us. We have prepared a proposal to Ford for this Department to offset this loss partially.

When Congress passed the International Education Act, the major foundations concluded that their priming of the pump in this field was done and very largely pulled out of it. Congress, however, failed to appropriate funds. For several years the Center for International Studies had an extremely useful Carnegie Corporation grant that enabled us to bring here such visiting professors as A. Doak Barnett, Shmuel N. Eisenstadt, Dankwart A. Rustow and others. Even more important, it supported our students doing thesis research abroad. For students in the comparative and development fields such work is essential. That grant has come to an end, and the Carnegie Corporation has left the international studies field. Nonetheless, we are seeking a partial renewal of this grant. Even contract-research support is threatened by current research cuts and particularly by the attacks by Senator Fulbright and others on the Area Studies and Behavioral Science programs of not only the Department of Defense but all mission-oriented Federal agencies. The funding crisis is a year off, but if no changes occur, it could be very serious for this Department and indeed for the nation.
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

FACULTY ACTIVITIES

Members of the Department served as consultants to at least eight agencies of the United States Government: Department of State — Professors Eugene B. Skolnikoff, Pye, Myron Weiner, and Griffith; Department of Defense — Professors Kaufmann and Pool; Office of Science and Technology — Professor Skolnikoff; AID — Professor Pye; Bureau of Budget — Professor Kaufmann; Peace Corps — Professor Johnson; Upward Bound — Professor Johnson; and Department of Housing and Urban Development — Professor Robert C. Wood (Under Secretary).

ITHIEL DE SOLA POOL

DEPARTMENT OF PSYCHOLOGY

The year under review marks the fourth anniversary of the inception of the M.I.T. Department of Psychology in 1964, and the seventh since the formulation of those initial plans which committed our efforts in teaching and research to three distinct but overlapping areas: brain and behavior (psychobiology); perception and learning (experimental psychology); and the study of early development of individuals and their interaction in groups (social-developmental psychology and psycholinguistics). In a time of restlessness and distress, when man builds better and better artifacts, yet is less able than ever to understand and control himself, the case for behavioral science at M.I.T. need no longer be made. The question is only how far and how fast we should go in our expansion.

Our intention is to continue with our present rate of growth, taking care that the growth remain symmetrical and orderly. We still take a perverse pride in being one of the smallest departments at the Institute, particularly since our enrollment in psychology subjects (for undergraduate and graduate students) is uncommonly large: The enrollment in 1966-67 was 1,309; this figure rose to 1,532 in 1967-68. At the same time, the staff increased only slightly in size. During the review period there were 12 members of the regular teaching faculty, aided by four part-time lecturers and two visiting professors.

This small group worked on 34 different research projects, ranging from large programs cutting across all three areas of our departmental concern to somewhat more specialized forms of experimentation. It is evident that each member of the group was alarmingly busy, although it should be added that the faculty was joined in its research activities by ten research associates and four D.S.R. staff members, who shared in
many of the ongoing projects, besides engaging in some projects of their own.

In keeping with our apprenticeship system, the 26 graduate students working full-time towards their doctorates were active partners in advanced research. If we add to this number the 38 members of our administrative, technical, and clerical staff, we see how the total census of the Department and its laboratories has managed to climb to 96 during the past year. In spite of continual subdivision and rearrangement of rooms and working spaces in our departmental building, it is clear that some additional space must be found soon, unless we want to curb even the most moderate further growth.

To assess the need for expansion, one has to look at what a group does with its facilities, and one has to ask whether each member is doing better or worse for being part of his setting. In these respects our total number may not be too far from its optimum. Yet, as we look at each of the three areas of departmental commitment, it is apparent that there are gaps. These gaps are in each of the areas, though they are more conspicuous in the second and third areas, those of experimental and of social-developmental psychology. To fill these gaps, we have to create additional faculty positions, one or two in each of three fields. Some of these additions may come as the result of internal redistribution, as they have in the past when members of the research staff shifted into faculty roles. A core group of 12 faculty members (comprising only three full professors) is a mere beginning; our efforts would be stunted if we stopped at that. As it is, our small faculty group is working at the limit of its capacity and will need help.

TEACHING

For the second consecutive year, an intensive discussion was held with the departmental Visiting Committee regarding the wisdom (or otherwise) of creating an undergraduate major in psychology. The verdict was, as before, that such a move would not be prudent at the present time. Nevertheless, a dozen different undergraduate subjects, covering the three areas of the departmental program, were offered during the year under review; and these attracted 1,388 undergraduates in all, an increase of 220 over the 1,168 undergraduates enrolled in psychology subjects in the preceding year, 1966-67.

In contrast, graduate enrollment (including cross-registration from other M.I.T. departments and from other academic institutions in Boston and Cambridge) stayed essentially the same: It went from 141 in 1966-67 to 144 in 1967-68. The over-all trends are shown by terms in Table I.
Table I Enrollment in Psychology Subjects 1966-67 and 1967-68

<table>
<thead>
<tr>
<th></th>
<th>Fall 1966-67</th>
<th>Spring 1966-67</th>
<th>Fall 1967-68</th>
<th>Spring 1967-68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduates</td>
<td>510</td>
<td>658</td>
<td>627</td>
<td>761</td>
</tr>
<tr>
<td>Graduate students</td>
<td>51</td>
<td>90</td>
<td>52</td>
<td>92</td>
</tr>
<tr>
<td>Term Totals</td>
<td>561</td>
<td>748</td>
<td>679</td>
<td>853</td>
</tr>
<tr>
<td>Academic Year Total</td>
<td>1,309</td>
<td></td>
<td>1,532</td>
<td></td>
</tr>
</tbody>
</table>

This table should be considered in conjunction with our full-time faculty census of 12 (or 14, depending on how the faculty is counted) and our census of full-time doctoral students of 26, in 1967-1968. It is quite evident that our student-faculty ratio for undergraduates is exceedingly high, being of the order of 100:1, in contrast to the comfortable ratio of approximately 2:1 between our doctoral students and their sponsors. The lesson to be drawn from these figures is plain: More staff is needed for teaching introductory subjects.

The alternative solution — that we curtail our undergraduate teaching — would be repugnant not only to the students, but to the members of our Department as well. The undergraduates are spontaneous and imaginative; in their reaction to faculty they are critical and direct. It is only by trying to explain to them, on elementary and intermediate levels, what we think we know from our own research that we begin to learn ourselves what our work might mean.

We stand to derive great benefit from contact with the M.I.T. undergraduates, who often are more gifted for work in the natural sciences and mathematics than are students majoring in psychology in other institutions. It is therefore all the more necessary that we increase the staff for undergraduate instruction and obtain space for undergraduate laboratories. So far, only a few undergraduates can join the faculty and graduate students in ongoing research.

RESEARCH

During the period under review, the Department's laboratories reported achievements in all three areas of concentration: brain and behavior, perception and learning, and social-developmental studies (including psycholinguistics). Faced with these diverse activities, a reviewer will have to be extremely selective, mindful of the fact that what seems merely a minor shift of emphasis in any one year may appear as a major turning point later on. As in previous years, a fuller account will be published separately, and details can be obtained by consulting the Department's publications, which numbered 93 this year.
In trying to grasp the relationship between brain and behavior, the ultimate aims are to understand what goes on in our own brain when we perceive, when we move, feel or express emotion, think, learn, or remember. On each of these questions the field is in an utterly primitive state. Yet we can see the beginning of fundamental disclosures.

Neural basis of perception The approach to sensory systems was reoriented drastically about ten years ago with the successful characterization of "feature-detectors," first for touch (by Mountcastle in the so-called sensory cortex of the brain), then for vision, where it turned out that aggregates of nerve cells in the visual cortex were capable of distinguishing lines and corners, and probably more complex configurations, by virtue of their own specialized connections. These discoveries, made independently by Professor Jerome Y. Lettvin and his colleagues at M.I.T., and by Hubel and Wiesel, were soon followed by similar disclosures about the auditory nervous system, suggesting cells specialized for recurring features of species-specific calls in frogs and cats. Much remains to be done in this area: It is still not clear how far up, so to speak, these systems for feature analysis can extend, that is, whether the line and direction detectors, by appropriate combinations, can lead to the recognition of that face among a thousand faces; nor is it clear what might correspond to those detectors in sensory modalities such as smell and taste.

Two contributions, from different laboratories within the Department, exemplify how our work might bear on these questions.

Two visual pathways It has commonly been assumed that the visual feature-extracting apparatus in higher mammals is largely represented by the visual cortex of their brain and that those parts of the visual system which do not lie on the direct route between the eye and that terminal region are secondary in function, if not mere vestiges of an earlier arrangement in evolution. Intensive investigation of visual systems in rats, hamsters, squirrels, tree shrews, and cats have convinced us that there are at least two largely independent and coordinate pathways, each carrying visual impulses all the way to the cortex: one to the striate cortex, the classical end station; the other directly to regions adjacent to the striate cortex. This duality of systems may help to explain why so much visual capacity remains when the striate cortex is lost, and why certain difficulties with vision tend to appear when the extrastriate regions are damaged selectively (Professor Walle J. H. Nauta and Paul L. Abplanalp).

Behavioral consequences of selective destruction of these at least partly separable systems are under active investigation (Professor Nauta,
Dr. Harvey J. Karten, and Professor Gerald E. Schneider). A particularly clear demonstration of such dual systems has been obtained by Professor Schneider, who first observed the distinct manifestations of visual loss in hamsters following removal either of visual cortex or of certain midbrain structures (the superior colliculi). His findings suggest that the midbrain structures aid the animal in localizing visual targets while the visual cortex permits it to distinguish and identify them. Whether this distinction will fit and explain the duality of visual structures that has been found on anatomic grounds is currently under careful investigation.

These studies derived additional precision from a new technique for tracing degenerating nerve terminals, the Fink-Heimer modification of Nauta's famous stain. This novel method, developed in Professor Nauta's laboratory, and described in last year's annual report, is now being adopted widely in other neurobiologic research centers in this country and abroad. With the help of this method, the duality of visual systems is being shown by Dr. Karten and his collaborators for the brains of birds, ranging from pigeons to sparrows and owls. The same techniques in the hands of Dr. Lennart Heimer and others in Professor Nauta's laboratory are also helpful in redefining the intricate neural connections between the organs of smell (the olfactory bulb) and the various way stations in what has been called the smell brain, or rhinencephalon. These studies of structure are closely related to a novel attack on olfactory function.

New approach to olfaction Modern techniques permit the insertion of a microelectrode into the olfactory bulb of animals while they react to various odors; yet no convincing classification of odor-bearing stimuli has been accomplished to guide such electrophysiology. A graduate student in Professor Stephan L. Chorover's laboratory, Foteos Macrides, has therefore decided to adopt a different approach, one that exploits the discoveries made by ethologists who study the animal in its natural habitat and try to define key stimuli of biologic significance acting as "releasers" for particular behavior patterns. A typical instance for birds would be the release of "mobbing" behavior in chaffinches upon exposure to the schematized cardboard dummy of an owl.

In rodents, certain complex odors have a similar releasing function. An extreme instance is the Bruce-Parkes effect: A female mouse, recently made pregnant, will terminate its pregnancy upon a single exposure to the smell of a "strange" male mouse. This remarkably direct action of an airborne chemical upon the neuroendocrine system of a mammal affords an opportunity for tracing the responses through the olfactory bulb and into other parts of the brain, by electrical recording during reception of the key odor. Moreover, the "strangeness" of the intruding
DEPARTMENT OF PSYCHOLOGY

male animal is a function of selective habituation to the familiar partner. This biologic system thus holds promise beyond a better understanding of odor perception: It may help in defining some forms of learning at the level of a single cell.

VOLUNTARY MOVEMENT Techniques of single-cell recordings by micro-electrodes recently have been extended to the motor system of mammals. It has been suggested elsewhere (by Evarts and others) that many of the large neurons in the monkey's motor cortex fire in regular relationship to certain movements of the monkey's hand; here, the cell's signaling precedes the muscular action. A fundamentally different arrangement, however, was explored in the Department's laboratories by Dr. Emilio Bizzi and Professor Peter H. Schiller in 1967. They obtained their recordings in the awake monkey from individual cortical cells in the so-called frontal eye fields in the brain. Stimulation of this area by large electrodes drives the eyes in predictable directions, and it was therefore assumed until now that the individual cells in these eye fields would act in the same manner as do the large cells in the classical motor cortex: Their discharge should precede a movement of their target muscles, that is, a movement of the eyes. Instead, the opposite was seen: Most of the cells in these frontal eye fields, although their fibers course downward into the eye-movement regions of the brainstem, were found to fire vigorously at the end of a given voluntary flick (saccade) of the monkey's eyes.

Each individual cell turned out to be specific in that regard: One, for instance, fired if, and only if the eyes had swept 30° to the left and up, another if, and only if the eyes had just completed a vertical downward movement of 10°. Other cells in the area were silent during and after eye movement, but appeared to signal movements of the head. The entire arrangement, totally unsuspected, gave a strong impression that these specific signals were related to the completion of eye movements, as if they provided a way for the organism to compare the success of a given phase in a sequence of movements with the intentions for making them. Major efforts now need to be directed at the question of where and how these "success" signals are further processed within the nervous system, but it is already apparent that revisions in our notions about voluntary movement seem to be required.

MEMORY Since the beginning of the 1960's, workers in numerous research centers in the United States and abroad have tried to discover the physical bases of memory and learning, obviously influenced by the spec-
tacular successes since the early 1950’s in the breaking of the genetic code. In spite of such concentration of efforts for over seven years, the evidence for specific molecular mechanisms in memory storage remains inconclusive.

*Loss of long-term memory after hippocampal removals in man*  Only one observation has become secure: the role of the hippocampus, a structure on the undersurface of the temporal lobes. Together with closely related systems in the brain, these curious structures seem to play a crucial role, not in learning as such, but in the transition from a short-term form of memory to long-term retention. As Scoville and Milner have shown, in the absence of this structure in man much of everyday behavior seems unchanged, but there is little or no capacity for the permanent acquisition of new memories, whereas old memories, stored before the operation, are freely recalled, and short-term memory for ongoing events seems quite unaffected. As far as new material is concerned, such a patient lives literally from one episode to another, unable to commit his experiences as they occur to a more permanent form. With the collaboration of the Montreal Neurological Institute (Dr. Brenda Milner) and Dr. William B. Scoville’s Neurosurgical Service in Hartford, Connecticut, the most striking of these cases has been restudied, in our laboratories and at the M.I.T. Clinical Research Center, by Dr. Suzanne H. Corkin, Dr. Thomas E. Twitchell, Professors Whitman A. Richards, Hans-Lukas Teuber, and Wayne A. Wickelgren, and others.

Similar but less severe effects were found in some cases of penetrating trauma, and these cases are being subjected to a correspondingly detailed analysis of their memory disorder, which can be remarkably specific, appearing in the absence of any significant loss in perceptual ability, attention, or intelligence.

*Inhibition of protein synthesis and blockage of learning*  The clinical observations and analyses just cited are directly relevant to an interpretation of those experiments in animals in which protein synthesis in the brain has been blocked by certain drugs (such as puromycin), and the concomitant deficits in learning studied. Unpublished observations from Professor Chorover’s laboratory by Mr. Macrides again indicate that the effect of such chemical agents may be selective upon the hippocampal zone, producing essentially a reversible chemical lesion in those areas critical for long-term memory. Thus, after a single application of puromycin, electrical activity of the rodent hippocampus remains grossly abnormal for many days. What takes place in the hippocampal apparatus when it is normally active, permitting this crucial transformation of immediate into long-term memory traces? It is likely that the next big step
will be an elucidation of the mode of action of individual neuronal units within the hippocampal zone.

PERCEPTION AND LEARNING
As in the past, the Department’s studies of perception and learning overlapped with one another, and both of them touched increasingly upon questions of psychophysiology, on the one side, and of developmental psychology, on the other.

PERCEPTION In considering perception, the central concern remained the question of how far the undoubtedly inborn mechanisms for feature-extraction could serve the perceiver in building up his perceptual world. The feature-detection system is necessary, as can be seen from the profound visual deficiencies of dark-reared kittens, who lose this innate neuronal machinery in their visual cortex, apparently irreversibly, as the result of early disuse. Yet the cortical apparatus for the detection of lines and corners, movements and direction of movements, and of colors and their interaction, is clearly not sufficient as a basis for the origin and maintenance of visually guided behavior.

In nearly all modalities, perception requires some interaction between the sensory input and the organism’s own output: Scenes shift as we move, and unless we can take our own active movements into account, the perceived world would be a jumble. The newly found complexity of visual systems may well be related to these requirements of bringing bodily movements into register with the impressions of a distant scene.

Perception in relation to movement The fundamental experiments that bear on this matter are those of Professor Richard M. Held and Alan Hein, and their various collaborators in the Department’s laboratories. Two complementary methods continue to be employed, one involving rearranged input, for example, the displacement and distortion of the scene obtained by wearing prismatic spectacles, and the other early deprivation, not of sensory input, as in rearing animals in the dark, but of self-produced output, a condition achieved by rearing kittens in such a way that they see a visually patterned world only during periods of passive motion, as when they are carried by another kitten in a gondola.

Prismatic distortions of vision, induced in normal adults, disappear or become much diminished when the wearer of the prismatic spectacles walks actively about; if instead, he is pushed around in a wheelchair, no adaptation to the distorted input results. Similarly, kittens reared without an opportunity to observe the visual consequences of their own active
movement fail to make normal depth discriminations: When removed from the apparatus, they need approximately a day's exposure to a visual environment in which they are allowed to move by themselves before normal sensorimotor coordination can appear.

Such profound differences in the perceptual consequences of active and passive movement have inclined us to believe that there must be an essential physiologic distinction between the two forms of motion, self-initiated versus passively imposed. Our view is, as we have said before, that active movement entails not only the classical command signals from the brain to the musculature, but a simultaneous dispatch of signals — a "corollary discharge"— from motor to sensory regions in the brain, presetting the sensory regions for the expected change in sensory input, that is, for that change which will result from executing the voluntary movement. This corollary discharge, while still hypothetical, becomes a heuristic tool; it can serve as a marker for the voluntariness of active, self-produced movement. Storing of correlations between such corollary discharges, during active movement, and the corresponding changes of the scene, may form the substrate for adaptation of normal adults to rearranged sensory input, and for the initial build-up of sensorimotor coordinations in the very young. A few experiments from a much larger number are cited here to illustrate this approach:

1. If our assumptions about a central processing loop in the nervous system are correct, then some critical interval would be required to produce any given motor output and to compare the consequent change in the input with what had been anticipated. Accordingly, prism adaptation was tested under conditions permitting active movement but limiting the view of the scene to brief repetitive glimpses, by means of stroboscopic illumination (Professors Held and Hein; Martin J. Steinbach, and others). The results suggested a time constant in the hypothesized control loop of about 1/10 second.

2. A normal observer can follow an external target that moves in regular motion (for example, a pendulum bob) with smooth tracking movements of his eyes unless the target oscillations become too rapid. With four reversals or more per second, smooth tracking becomes impossible, and the eyes engage in saccadic movements to regain fixation. The situation is quite different when the observer tracks a target affixed to his own hand. He now can track smoothly at much higher rates of movement and reversal, indicating that his own outgoing motor signals to the hand can enter into the central regulation of his eye movements (Mr. Steinbach and Professor Held). If the hand is moved passively, by an external apparatus, this superior tracking performance breaks down
and the eye movements approximate those seen in the case of an entirely external target, not attached to the observer's body.

3. As a seen object approaches the eyes or recedes from them, the apparent size of the object does not change as much as the laws of perspective would suggest. This phenomenon, traditionally called "constancy" of perceived size, is found most clearly over that range of distances over which convergence movements of the eyes can operate, and there is a great deal of experimental evidence that associates abnormal convergence movements with anomalies of size perception. A most direct approach to these phenomena is being developed by Professor Richards, who postulates that any vergence movement of the eyes entails corollary discharges to the visual system, possibly entering it at a major way station between retina and visual cortex, the so-called lateral geniculate body. This exquisitely layered structure has so far defied all attempts at explaining its function; in fact, it remains a mystery why the major visual pathways should be interrupted at all instead of coursing directly to the striate cortex. Richards' theory assumes that the cortical receptor fields in the visual system are not fixed; instead, the mapping of these fields changes concomitantly with convergence and divergence upon near and far objects, the entire arrangement acting so as to provide a "remapping" or "zoom" effect, in which the visual field can change its grain, counteracting to some degree the shrinkage in the projected size of seen objects, as they recede from the eyes. Numerous psychophysical experiments on man are being undertaken to check quantitative predications derived from this theory; at the same time, Professor Richards and Dr. Bizzi have probed the monkey's lateral geniculate body with microelectrodes to find more direct correlates of the proposed remapping of the visual field during eye movements.

TEMPORAL FACTORS IN THE VISUAL PERCEPTION OF PATTERNS AND MOVEMENT One of the classical problems in vision is the question of how successive impressions interact to build up a coherent view of the world. Rapid interaction can be studied by presenting a flash of light or a pattern for a moment and then following it, after variable intervals, by another flash or pattern which falls either onto the same part of the visual field, or onto some area adjacent to that occupied by the first stimulus. In the first case, one can expect masking or, more rarely, facilitation; in the second case, one usually obtains what has been called meta-contrast.

The standard demonstration of meta-contrast involves presenting a disk, followed by a ring, with the inner contour of the ring falling into
those parts of the visual field which had previously been occupied by the outer contour of the disk. With the appropriate choice of intensities and durations of successive stimuli, and of the time interval between them, one can produce effects akin to the obliteration of the disk, although careful experiments by Professor Schiller and his students have shown that the disk is not really rendered invisible but converted into a peculiar, radially expanding gray pattern which "turns into" the ring. These observations suggest that the phenomenon of meta-contrast may be a special case of apparent movement. More recently, Professor Schiller has confirmed his earlier reports that the effect occurs readily from eye to eye (that is, on "dichoptic" presentation, where one eye receives the disk, the other the ring). Beyond this earlier finding, Professor Schiller now can show that such dichoptic effect is actually stronger than a monoptic one, that is, the effect obtained when the two successive stimuli impinge on the same eye.

In parallel electrophysiologic explorations, Professor Schiller is searching for correlates of such meta-contrast effects at the level of single cells in the cat and monkey lateral geniculate. In addition, monkeys have been trained, in collaboration with Dr. Charles Gross, now at Harvard, to make differential responses to visual stimuli presented under what for man would constitute meta-contrast conditions. This training has been successful; it is a prelude to further experiments involving electrical recording from extrastriate cortical regions, notably the inferolateral temporal lobe cortex. Ablation of these structures in the monkey leads to lasting impairment of performance on many visual discrimination tasks. It is expected that temporal interaction of successive visual stimuli will also be affected following bilateral ablation of this inferotemporal neocortex.

So far, recording of single-unit activity from this important area, in the course of stimulation by visual patterns, has revealed only responses to diffuse light; but recently, Professor Schiller and Dr. Gross have encountered units in the inferolateral temporal region which fire vigorously whenever the animal seems to "pay attention" to some object in his visual field.

LEARNING AND SHORT-TERM MEMORY PROCESSES  It is generally conceded that all learning begins with the engaging of some short-term memory (STM) mechanism. In a series of elegant experiments, Professor Wickelgren has explored the decay rates of such short-term traces for different kinds of material and for different rates of presentation of the material. He found that for a series of letters presented at rates of 1, 2, or...
4 letters per second, the decay in the strength of the short-term trace (measured by tests of recognition) did not depend on the number of items that followed a given item in the series, but depended quite directly on the rate of presentation, the decay being fastest for rapid presentation (4 per second) and least for the slowest presentation (1 per second). Apparently, these short-term traces decay exponentially, with the shortest falling to half strength in about 2 seconds.

Long-term traces for verbal material were studied by teaching English-speaking adults 240 Russian-English word pairs, with training sessions given twice a day for several weeks. Retention was tested at delays ranging from 2 weeks to 1 year. The rate of decay in trace strength was phenomenally low, the traces falling to half strength in about a year. Since the shortest of verbal short-term traces (in the experiment on letters) decays to half strength in about 2 seconds, there seems to be a factor of approximately $10^7$ between decay rates for verbal short-term and long-term memories.

In a special extension of these experimental techniques to a classical case of memory disorder after bilateral hippocampal removal, Professor Wickelgren was able to show that this man did, indeed, have an essentially normal short-term memory, in the virtual absence of capacity for establishing long-term traces.

Intensive work has also continued on pitch memory in normal adults, and on mathematical theories for the detectability of auditory signals at different frequencies, under conditions for which the frequency of the test sound either is known in advance, or is not known to the listener. These and similar experiments have led Professor Wickelgren to a critique of those psychophysical scaling procedures for signal detectability which use the standard deviation of the total noise in the probability data as the unit of measurement.

EARLY DEVELOPMENT OF SENSORIMOTOR CAPACITIES, LANGUAGE, LOGIC, AND SOCIAL INTERACTION

As in previous years, research activities in the third area of the departmental program focused on studies involving early deprivation or early cortical lesions; on normal perceptual and linguistic development; and on the acquisition, by children, of logical structures and social values. Work on each of these topics will be illustrated by a few examples.

EARLY DEPRIVATION Numerous previous experiments in the departmental laboratories (by Professors Held, Hein, and their colleagues) had shown that active movement is a prerequisite of adaptation by normal
adults to rearranged sensory input (as in prism studies), and that active movement played an equally central role in the initial acquisition of sensorimotor coordination. Thus, kittens carried about passively in a gondola while looking at their visual environment did not achieve normal perceptual-motor coordination until permitted to locomote actively for a day with respect to the visual scene. This experiment has now been varied and fractionated, so to speak, in several ways:

**Raising of kittens in stroboscopic light** Even though active movement be permitted, normal sensorimotor coordination will not appear if the scene is illuminated intermittently by very brief flashes (below 100 milliseconds), as has been done in a series of new experiments by Professor Hein, who raised kittens under stroboscopic light. Flash durations above one-tenth of a second, however, are compatible with normal perceptual-motor development.

**Raising of kittens and monkeys without permitting them to see their limbs** Another variant of deprivation studies involves the device of raising young animals from birth under conditions in which they can see the environment while actively moving their head and body, but cannot see one or several of their own limbs. In experiments of this type with kittens, by Professor Hein and Ellen C. Gower, the sight of limbs is precluded by the simple device of fitting the animals with an opaque collar; the result of such restricted condition of rearing is a kitten that shows "visually triggered" but not "visually guided" reactions of his limbs. When rapidly moved toward a solid surface, these kittens react by extension of their limbs, exhibiting a visually triggered response, but they fail to place their limbs accurately onto the protruding portions of a serrated edge, indicating that they have lost the normal visually guided responses of their limbs. By making half of a collar transparent, leaving the other half opaque, the deprivation can be restricted to one forelimb, which then shows no visually guided placing reactions, while the other limb does.

In similar studies on very young monkeys, the animals are raised in padded chairs with an opaque plastic barrier precluding sight of their own body. A new generation of stumptail monkeys born in the laboratory colony is now being reared in this fashion and tested upon release from the apparatus by Professor Held and Joseph A. Bauer. It is apparent that there is no coordination between eye and hand in these animals upon first sight of their hand, when the opaque barrier has been removed: Episodes of intense inspection of the hand alternate with flailing movements which do not turn into coordinated patterns of visually guided reaching until several days after release. We assume that during normal
exposure of the moving hand to the eye a young animal "maps" his motor system into his visual system.

STUDIES INVOLVING EARLY CEREBRAL LESIONS The critical importance of certain aspects of early exposure, for subsequent normal development, may be one of the reasons why early brain injuries are often said to have effects different from analogous lesions sustained later in life. On the other hand, the possibility has never been excluded that the organization of the young nervous system may in itself be more plastic than that of older individuals. A series of experiments has been inaugurated recently in order to test these issues.

Early versus late removal of striate cortex in kittens Experiments by Professor Hein now in progress contrast the behavioral effects of very early removals of striate cortex (visual cortex) in kittens with the effect of similar removals in mature cats. In line with earlier reports by others (for example, Doty), the early removals produce much less of a visual handicap, as measured by those tasks which have been developed in the Department's laboratories for the assessment of visually triggered and visually guided reactions after special forms of rearing.

Early cerebral removals in hamsters A possible clue to the reasons for such a sparing of functions after brain lesions in very young animals comes from ongoing studies of Professor Schneider, in close contact with Professor Nauta's group: If parts of the "second visual system," that is, the so-called superior colliculi in the midbrain, are removed soon after the hamster's birth, an actual anatomical reorganization seems to take place. Fibers that normally would end in that structure now sprout new terminals along their course in a nuclear complex of the thalamus (the lateral posterior nuclei) which would normally have received secondary fibers from the colliculi. Both observations — the redirection of fibers and their selective affinity for the structures within the system to which they "belong" — are novel, and both are of fundamental importance, even if it should turn out that the situation in other species might be somewhat different.

Effects of early brain injury on child development Throughout the year, a number of investigations by Dr. Corkin, Dr. Rita G. Rudel, Professor Teuber, Dr. Twitchell, and others continued to be concerned with the behavioral consequences of early (usually congenital) brain injury in children. Two examples are given here:

1. One of the current attacks on the problem of early versus late lesions in man is to adapt for use with children those tasks which have already been found to be particularly sensitive to brain lesions incurred in adult-
Accordingly, Professor Teuber and Dr. Rudel have tested children with mild congenital brain damage on a spatial-orientation task which in adults (with brain injuries sustained at maturity) tends to be done poorly after lesions to the parietal lobes. Performance on this task turned out to be remarkably vulnerable to even minimal brain damage incurred in early childhood; beyond that, a curious qualitative difference in performance was noted between the children with early brain damage and the adults whose lesions were sustained later in life: The children, but not the adults, consistently avoided diagonal paths on this test which involved the following, by active locomotion, of a variety of routes laid down on maps.

2. For the normal adult it is not too difficult to identify an object seen with the same object felt; but it has often been claimed that such transfer of sensory information across different sense modalities is more difficult for young children, and is impaired selectively after early brain injury. Yet it may be premature to invoke, as others have done, such an alleged breakdown of “intersensory integration” in children with early brain injury; the impression seems to have come from incomplete experimental tests.

In the normal child, transfer of information from vision to vision, as in matching an object seen previously against the same object presented among others in a series, is by far the easiest task (Dr. Rudel and Professor Teuber). In contrast, transfer from touch to touch in which a palpated object has to be matched against the same object in a series of objects to be palpated, is very difficult. Lastly, those tasks which force the child across boundaries between sense modalities are of intermediate difficulty; that is, tasks involving the transition from vision to touch, and touch to vision are harder than purely visual, and easier than purely tactual tasks.

Early brain injury alters the situation only insofar as the injured child finds the purely visual tasks much more difficult than does the normal child, so that the performance of brain-injured children becomes impaired under all conditions in which vision is involved — on visual-visual, visual-tactual, and tactual-visual tasks. There is no evidence, then, of a selective loss in capacity for cross-modal transfer after early brain injury in man (Dr. Rudel and Professor Teuber).

NORMAL PERCEPTUAL AND LINGUISTIC DEVELOPMENT

The concentration of efforts on abnormal children did not detract from similarly intensive concern with various aspects of normal child development, particularly with regard to the perception of complex visual and acoustic patterns. These studies reflect our continuing interest in the role of the
presumably innate feature-detection systems. We believe these systems may play a special role in the infant's early reactions to the human face, and to those particular acoustic patterns that, later on, become distinctive features of phonemes in human language.

**Children's recognition of faces** It is known that children are less skilled than adults in distinguishing snapshots of unfamiliar faces. For this reason, it was surprising to find that young children definitely surpass adults in the recognition of highly schematized line drawings of faces (Robert K. Yin). In these diagrams, identical line elements are arranged within an oval outline, the only variation being the relative distance among elements, and their distance from the surrounding outline. Adults complain that these "faces" look very much alike, whereas children distinguish them quite promptly and naturally, as if the schemata, with their intrinsic relations, were processed in some fashion that differs rather profoundly from the processes employed by adults. These unexpected results increase our suspicions that children categorize faces according to certain rules, some of which might well be innate.

**Early discrimination of phonemes by infants** A similar "nativistic bias" runs through a series of experiments by Professor Jerry A. Fodor, Dr. Merrill F. Garrett, and Dr. Kenneth I. Forster, in which normal infants are exposed to various speech sounds and their reactions to these sounds are noted. It had sometimes been asserted that language learning in the human baby might proceed as follows: The infant articulates various sounds, randomly at first, and retains those that are selectively rewarded by the adults around him. The difficulties with this interpretation lie in the fact that the child has to be able to discriminate well-formed from ill-formed sounds, and that he seems actually capable of doing that long before he can properly articulate the various speech sounds himself. It is probably not too far-fetched to assume that human infants are equipped with special feature-detectors for speech sounds. If this were so, certain universal features of human language should have greater arousal value, or be noticed and distinguished more readily than other acoustic features which do not form part of any known language.

As an experiment intended to bear on this fundamental question, Professor Fodor and his colleagues, especially Dr. Garrett, are conditioning human infants, several weeks of age, to react by head turning to various consonant-vowel combinations. So far, it seems that those syllables which sound similar to the adult ear (despite great dissimilarities in physical acoustic pattern) evoke similar responses in the infant — that is, conditioning to one such pattern readily transfers to the other pattern — whereas sounds that seem dissimilar to the adult listener have no such
effect on the infant. This work continues; it has obvious implications for one’s notions of how first-language learning might proceed, and why it is that modern linguistics has disclosed certain linguistic universals, features shared by all known languages in spite of their obvious diversity.

ACQUISITION OF SOCIAL NORMS The acquisition of language by the young child is clearly dependent on exposure to adults who speak within the child’s hearing, yet the articulatory patterns, and perhaps even some aspect of syntactic structure, are built, we believe, upon some inborn substrate that is common to all languages. Can the acquisition of social norms be interpreted in a similar way, as the result of an interplay between an intrinsic “competence” on the part of the child which then matures and is shaped in contact with adult social norms? Several studies were undertaken to probe these difficult but important issues.

Development of social norms in children: the role of influence by peers Much of the recent work on social (moral) development in the departmental laboratories has employed Kohlberg’s scale of moral development, a scoring system that attempts to provide more differentiated stages than does Piaget’s prototypical description. With the use of this scale, it becomes possible to assess the level of a child’s moral development, by rating his judgment of various hypothetical situations; the child is then given an opportunity to discuss these situations with another child whose moral development is either above or below that of the first child (Professor Herbert D. Saltzstein). A strong tendency emerged for the child who was at a slightly lower level to be influenced by the one on the higher level, rather than conversely. So far these studies, by Dr. Rhea Diamond, has been limited to boys between 10 and 11 years.

Social influence: example versus precept In another series of experiments by Professor Saltzstein and Maury K. Moore Jr., children were taught the rules of a game in the presence of two adults, one of whom presented the rules by acting them out, the other by stating them explicitly. This situation permitted the experimenters to put precept (the verbal statement) and example (the acting-out) in direct conflict and to observe what children of different ages might do under these conditions. It became apparent that the silent example was much more effective than the verbal precept, the more so, the younger the child.

CONCLUDING REMARKS

As we said initially, this review of our investigations had to be selective in what has been included and arbitrary in its emphasis. We hope, nevertheless, that the principal trends in the departmental research program
can be discovered from what has been said. In spite of their apparent diversity, the projects within the Department's laboratories share a number of themes: the concern with basic mechanisms in perception and the role of innate "rules" for processing sensory input; the concern for a fundamental distinction between active (voluntary) and passive movements; the growing commitment to work on memory at all levels, from classical experiments in human learning to a search for the mechanisms of retention at the level of the single cell; most of all, a shared belief that behavioral science is not going to find the answers to the problems of perception and action, memory and learning, if one looks at any one of these questions in isolation from the others.

Behavioral science is still far more of a promise than a real achievement, a point taken by William James three-quarters of a century ago, and still as true now as then. We are committed at M.I.T. to help build this science by drawing upon the resources of current natural and social sciences and of mathematics. In these efforts, we have the help of our graduate and undergraduate students, who come to us with a conviction that behavioral science can and must form part of the basic sciences. The research program of the Department is thus readily integrated with its commitment to teaching; and both, we believe, fit into the framework of M.I.T. It is equally true that a department as unorthodox as ours could not have grown up anywhere else but at the Institute. Yet, as we said initially, the small group carrying the departmental program will need more help, if we want to maintain what we have and continue even the most moderate growth.

HONORS AND SPECIAL NATIONAL AND INTERNATIONAL SERVICE

The faculty continued to share in various national and international functions. In June, 1968, Professor Held concluded his term of duty as chairman of the Experimental-Psychology Study Section of the National Institutes of Health; he continues to serve on the Board of Scientific Advisors of the American Psychological Association, and on the Vision Committee of the National Research Council. He was elected a Fellow of the American Academy of Optometry.

Professor Nauta served on the teaching commission to Iran for the International Brain Research Organization (IBRO, World Health Organization), and was active on the Committee on Research in the Life Sciences of the National Academy of Sciences. He also continued his service on the Biological Stain Commission and on the Selection Board for Research Career Awards of the National Institute of Mental Health. In the summer of 1967 he represented the United States at the Sarkisov
Institute in Moscow, at their anniversary celebrations, and in the spring of 1968 he gave the annual Carlson Lecture at the University of Chicago.

Professor Teuber served as American delegate to a Paris meeting of IBRO, concluded his service on the Neural Sciences Study Section of the National Institutes of Health, and continued on the NASA Biosciences Subcommittee and the Task Force on Behavioral Biology of the National Academy of Sciences. He was elected a Foreign Member of the French Psychological Society and an honorary member of the faculty of the National Institute of Neurology of Mexico.

In the summer of 1967, Professors Held and Teuber and Dr. Twitchell attended the XIII International Neuropsychology Colloquium (held that year in Brittany) as invited participants. Subsequently that summer Professor Teuber gave a memorial address for the late Wolfgang Köhler at the Free University in Berlin, Germany, and lectured at a NATO Summer Seminar held at the Stazione Zoologica in Naples, Italy. In the fall of 1967, Professors Richards and Teuber took part in the International Conference on Neural Communications arranged by Professor Donald MacKay (with the advice of Professors Eccles, Jung, and Teuber) at Keele, Staffordshire, England. In May, 1968, Professor Teuber served for three days as Distinguished Philips Lecturer at Haverford College in Pennsylvania.

Among the younger members of the group, Dr. Karten was twice honored during the spring term 1968. He won the C. J. Herrick Award for outstanding contributions to comparative neuroanatomy from the American Society of Anatomists; soon thereafter, his recent atlas of the pigeon brain (with Hodos) was given the annual prize of the Chicago Book Clinic.

COLLOQUIUM PROGRAM
The sequence of approximately weekly colloquia, by staff members and guests, is now an established feature of the Department's teaching program. In the year reviewed, there were 48 such colloquia. Among the speakers, 16 came from abroad.

STAFF CHANGES
During the year the Department acted as host to two visiting professors. From Stanford University, Professor Frank Morrell came for the fall term; his stay at the Institute was jointly sponsored by Professor Frank Schmitt's Neurosciences Research Program and by the Department of Psychology. Professor Morrell shared with us, in lectures and less formal discussions, some of his recent work on the conditioning of single cells in
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the mammalian cortex. His wife, Dr. Lenore Korkes Morrell, a former graduate student of Professor Teuber, worked during the same period in the latter's laboratory on evoked cerebral potentials in man.

For the entire year, Dr. Neville P. Moray, Senior Lecturer at the University of Sheffield in England, joined us as an Associate Visiting Professor of Experimental Psychology, under the combined auspices of the Department of Psychology and the Research Laboratory of Electronics. Professor Moray divided his time between work on figural aftereffects in vision, including an attempt at computer-simulation of these perceptual phenomena, and the development of mathematical theories for selective attention. These theories were based on experiments with normal observers who had to listen to different messages presented either alternately or simultaneously to parallel sensory channels such as the two ears or the two eyes.

As to the regular faculty, we have to report two arrivals (by virtue of promotion from research-associateship and lecturership, respectively), balanced by two impending departures. In September, 1968, Associate Professor Joseph Altman, widely known for his work on radionurometry, will assume his new duties as Professor in the Biology Department at Purdue University. The call comes in recognition of Professor Altman's major contributions to research in neurobiology. His close associate, Dr. Gopal D. Das, will also move to Purdue; another of Professor Altman's associates, Dr. Robert B. Wallace, will assume a post at a neighboring institution.

Also in September, Dr. Herbert Saltzstein, now associate professor in social psychology, will move to Sarah Lawrence College to assume a professorship there. His enthusiastic interaction with M.I.T. undergraduates has contributed greatly to the teaching of psychology at the Institute, and his investigations of social-developmental issues have been an important source of stimulation for our graduate students and staff.

The two arrivals on the faculty bracket the academic year: at the beginning of the fall term 1967-68, Dr. Gerald E. Schneider moved from a research-associateship into an assistant professorship. He received his entire graduate and postdoctoral training at M.I.T., primarily in brain-behavior studies, concentrating on the mammalian visual system, and on the effects of early lesions in visual pathways on surviving visual function. This work has led to the discovery of a heretofore entirely unsuspected plasticity of central nervous connections.

At the end of the year Dr. Merrill F. Garrett, until now a lecturer in psycholinguistics, was moved into an assistant professorship. A graduate of the University of Illinois and an astute investigator of early child
development and of linguistic and perceptual problems, Dr. Garrett will continue his contributions to research and teaching in the third area of departmental endeavor, that of social-developmental psychology.

In addition, we are happy to report the promotion of Dr. Peter H. Schiller from Assistant to Associate Professor. His interests range widely, covering the areas of visual perception and psychophysics, personality, and child development.

Among the members of the research staff, one change of appointment should be noted especially: Joseph A. Bauer, who has been engaged in numerous experiments on perception and early development, and who has been in charge of our primate colony, became a research associate in Professor Held's group.

Also in the course of the year, several research fellows, associates and lecturers either completed or began their work with the Department. The arrivals included, as research associate, Dr. John R. Frederiksen, who came for one year to work with Professor Teuber and has now accepted an assistant professorship at Brandeis University. Dr. Hans Zeier, from Zürich, Switzerland, began work with Professor Nauta and Dr. Karten, under a Swiss government stipend; he will continue this work for a second year, under the same auspices. Dr. Carl Chi came from Yale on a National Science Foundation postdoctoral fellowship to work in Professor Nauta's group; he, too, is extending his fellowship into a second year. In addition, Dr. Kenneth Ian Forster, who arrived from Australia to join our psycholinguistics group as an associate in research and a visiting lecturer for the academic year 1967-68, will assume his new position as Senior Lecturer at Monash University in Clayton, Australia, in the fall of 1968.

In March, 1968, Dr. Emilio Bizzi, who had been a research associate from September, 1966, until June, 1967, and a lecturer since then, left for Milan, in his native Italy. He is setting up a laboratory in the Medical School, where he plans to continue his fundamental studies on the visuo-motor system. In June, 1968, Dr. Arthur Taub, after three years as a special fellow under a career development award sponsored by Professor Teuber, is beginning an assistant professorship in physiology at the Yale Medical School.

In the coming academic year, we expect a visit from Professor Donald MacKay from Keele, Staffordshire, England, who will spend several weeks in the Department in the fall term. For the spring term, we expect to see Dr. Bela Julesz, head of a department at the Bell Telephone Laboratories, who will teach a seminar in perception from February through May, 1969. These and other visitors will share in our interaction
with graduate students whose census will increase to about 30 for 1968-69, as the result of seven new admissions. (There were 75 completed applications out of 205 inquiries.) There will also be three new postdoctoral students, bringing the census in that category to six.

In the course of 1967-68, four of our graduate students obtained their doctorates. Donald G. MacKay accepted an assistant professorship at the University of California at Los Angeles, where he is teaching physiological psychology and psycholinguistics. Christiana Morison Leonard went to Rockefeller University, where she is continuing her work in psychobiology. Valerie B. Domesick, after successfully defending her thesis in the summer of 1967, continued her work for an additional year with Professor Nauta before accepting a faculty position at the Boston University Medical School. Paul L. Abplanalp, who obtained his doctorate in June, 1968, will assume a research position at Pennsylvania State University in the fall of 1968.

FOREIGN VISITORS

As in previous years, we had the privilege of receiving a number of visitors from abroad, who toured our laboratories and exchanged information on their and our ongoing work. Many of these visitors came for one day or several days; some stayed for a week or more. On scanning our laboratory calendar, we realize that the largest number of visitors, as in the past, came from England and Scotland. From London, we saw Dr. Huggins, Dr. Piercy, and Dr. Steiner. From Cambridge came Dr. Broadbent and Professor Zangwill, and Dr. Moyra Williams; from Oxford, Dr. Kinsbourne, and Professors Weiskrantz and Whitteridge; from Keele, Professor MacKay; from Edinburgh, Dr. Marshall and Professor Walsh; and from Sussex, Professor Sutherland. The second largest number of visitors came from France, not surprisingly so in view of the frequent exchanges between us and the Institute of Experimental Psychology at the Sorbonne and the École Pratique des Hautes Études in Paris. The French visitors included: from Paris Dr. Barbizet, Dr. Hatwell, Dr. Lecours, and Mme. Vincent, as well as Professor Henry Hécaen, and Dr. F. Michel from Lyon. From Germany we saw Dr. Götze (Heidelberg), and Professors Ploog (Munich), Schmidt (Heidelberg) and Zülich (Cologne). From the U.S.S.R., we had visits from Dr. Bushorova (Leningrad) and later from Professor Paul Simonov for a day, and Dr. Inessa Koslovskaya for one week, both from Professor Asratyan’s Institute of Higher Nervous Activity in Moscow. From Chile, there came Dr. Teresa Pinto-Hamuy (Santiago); and from Canada, we saw Dr. Doreen Vanderwolf (London, Ontario) and Dr. Brenda Milner (Montreal); from
Italy, came Dr. Braitenberg (then at Naples) and Dr. Berlucchi (Pisa); and from Israel the Drs. Kreitler (Tel-Aviv). Dr. B. Inhelder (Geneva) visited for a day from Switzerland; the Drs. Gloning came from Vienna, Austria, for the larger part of one term, their main base being the Neurology Service at the Massachusetts General Hospital. Dr. El-Abd came from Egypt, and Professor Bures from Prague managed a brief visit at the end of a Neurosciences meeting at the American Academy of Arts and Sciences.

HANS-LUKAS TEUBER

CENTER FOR INTERNATIONAL STUDIES
The Center's research continues to be described conveniently under the four general headings of economic and political development, international communication, military and foreign policy, and Communist studies. A fuller description of research in progress, of Center publications, and of other activities not reported here will be found in the Center's latest Research Report, published in the spring of 1968.

PROBLEMS OF ECONOMIC AND POLITICAL DEVELOPMENT
The Center has continued to give much of its attention to the economic and political problems of developing nations. Its new collaborative research and training program with the Oficina de Planificación Nacional in Chile (ODEPLAN) is now well under way, with Chilean and Center-sponsored economists working together on broad studies concerning the methodology of planning and on current economic problems. The program is under the joint direction of Professors Max F. Millikan, Paul N. Rosenstein-Rodan, and Richard S. Eckaus. Peter B. Clark, formerly Assistant Professor of Economics at the University of California at Los Angeles, went to Chile last December on a two-year assignment. He is working on the formulation of programming models which will enable long-run projections for the Chilean economy. Carlos Diaz-Alejandro, Associate Professor of Economics at the University of Minnesota, spent January through March in Chile studying problems of Latin American integration. Three appointments have been made for full-time research there next year: Dr. Edmar L. Bacha of Yale; Dr. Jere K. Behrman, Associate Professor at the University of Pennsylvania; and Dr. Lance J. Taylor, from the Center for International Affairs at Harvard University. In addition, five economists served with the project last summer: Professors Eckaus, Rosenstein-Rodan, Paul H. Cootner, and Franklin M. Fisher of M.I.T., and Professor Hollis Chenery of
Harvard. A professional staff from Chile will be working with the visiting economists, and other Chileans will be coming to M.I.T. and other appropriate universities for graduate training.

In another collaborative research venture, the Center has been analyzing social and economic change in cooperation with the Centro de Estudios del Desarrollo (CENDES) of the Central University of Venezuela. Professors Frank Bonilla of M.I.T. and José A. Silva Michelena of CENDES have been working on two further volumes in their three-volume series on *The Politics of Social Change in Venezuela*. Volume 1, *A Strategy of Research on Social Policy*, was published last year by The M.I.T. Press.

The Center organized a six-week study conference this past summer to explore the relationship between political and social change in underdeveloped countries and the objectives and conduct of United States foreign aid programs. The conference brought together leading scholars from various disciplines who have done research on the problem, and officials from the Agency for International Development experienced in dealing with development problems. A similar intensive summer study on the means of increasing agricultural production in underdeveloped countries, held in the summer of 1964 under the auspices of the Agency for International Development (AID), resulted in a book by Professor Millikan and David Hapgood. *No Easy Harvest: The Dilemma of Agriculture in Underdeveloped Countries*, published in the fall of 1967 by Little, Brown, discusses the problem in terms of four major sets of factors — physical requirements, the economic environment, research and education, and the organization of agricultural development — and identifies the complex of development needs peculiar to each of four different ecological regions.

Professor Myron Weiner has begun a study of Indian voting patterns through the development of a data bank containing Indian electoral statistics and census data. Using the ADMINS data-processing system developed at the Center, he intends to undertake a number of specific studies in Indian voting behavior and to examine certain currently untested propositions about the relationship between economic development, social change, and political behavior. Professor Weiner has also continued the work begun in Europe last year on the theoretical and comparative problems posed by changing patterns of political participation and political organization. He is seeking to develop empirical, testable propositions about contemporary political development from a study of the modernizing experience of eighteenth- and nineteenth-century Europe.
Research on attitudinal and behavioral dimensions of the modernization process has been progressing under the direction of Professor Frederick W. Frey. In the last year, a pilot study was begun of the high schools of Bridgeport, Connecticut, designed to improve methods of assessing the power, influence, and communication structures of small- and medium-size organizations. The interviews for the study now have been completed, and work has begun on developing a methodology for analyzing the data. In conjunction with this task, research is going forward on computer data-processing systems capable of handling large-scale sociometric information. Analysis is also being carried out of existing hypotheses and data related to the modernization process as a guide to the selection of the critical variables which later could be analyzed through field work in the developing countries. A bibliography has been compiled on survey research of a cross-cultural nature relating to the development process and reported in English-language journals. It will be published by The M.I.T. Press.

Another aspect of the modernization process is being explored by Professor Lucian W. Pye, who is developing a program of comparative research designed to assess the different psychological and cultural attitudes and predispositions which have been critical to the national development of several different societies in Asia. This research will build upon his recent work on China, as well as his earlier study of Burma. Several M.I.T. graduate students are collaborating in the undertaking and will spend a year or more in field work in countries such as Malaysia, Indonesia, and Thailand. Professor Pye's recent research on Chinese political behavior has resulted in a book, *The Spirit of Chinese Politics: A Psychocultural Study of the Authority Crisis in Political Development*, which was published early in 1968 by The M.I.T. Press. In this book, he examines China's present political status from the perspective of China as a modernizing society. The emphasis is on the roles long played by authority, order, hierarchy, and emotional quietism in Chinese political culture as shaped by the Confucian tradition and the institution of filial piety, and the confusions brought about by the recent displacements of these traditions.

Two other books in political and economic development were completed at the Center last year. The Center's ten-year research effort on Indian economic development resulted in a book by Professor Eckaus and Dr. Kirit S. Parikh, to be published by The M.I.T. Press, which has broken new ground in applying modern computer techniques to the problem of formulating effective development programs. Entitled *Planning for Growth: Multisectoral, Intertemporal Models Applied to India*, the book
describes the structure of three types of linear programming model by which one may explore the mobilization and optimum use of resources while taking explicit account of sectoral and temporal factors. The authors analyze the solutions of these models when applied to data from India's Third and proposed Fourth Five-Year Plans and conclude with some new insights into Indian economic policy.

Professor Willard R. Johnson has completed a book on the Federal Republic of Cameroon, a union that has reunited much of the area of the former German colony which had been divided between British and French administrations under the Mandate and Trusteeship Systems. His study, entitled *The Cameroon Federation: Political Integration in a Fragmentary Society*, adds to and critically analyzes the existing literature on the theoretical aspects of the integration process and provides a case study of one nation's achievement of a relatively high level of integration among political communities of disparate cultures, economic patterns, and colonial legacies. It is being published by the Princeton University Press.

**STUDIES IN INTERNATIONAL COMMUNICATION**

In the past several years, Professor Ithiel de Sola Pool has been directing a program of basic research on aspects of the communication process relevant to international security problems. Research thus far has concentrated on the communication systems of China and the Soviet Union in an effort to learn more about information flows within these two countries. Six major manuscripts have emerged from the project, most of which are being revised for publication: "The Effects of Mass Communication in Communist China" by Dr. Paul Hiniker; "Communication and National Integration in Communist China" by Dr. Alan Ping-lin Liu; a manuscript by Dr. Frederick T. C. Yu on the impact on the individual of mass campaign efforts; Gayle Durham Hollander's study of "Communications and Social Modernization in the Soviet Union"; "How Russians Read Their Press: Patterns of Selection in Pravda and Izvestia" by Dr. Rosemarie Rogers; and a study of "Barbarossa" by Barton Whaley, which concerns communications in wartime to top decision makers.

One of the major contributions of the project has been the development of a computer information-processing system that can integrate many types of data, such as media circulation, census figures, audience response, radio and television coverage, news broadcast frequency, jamming, and censorship. A simulation model has been built which has promise of producing considerably more refined estimates than are now possible about the process by which information is diffused. An effort has now begun to program other versions of the simulation model, which now
operates only on the Computer Time-Sharing System of M.I.T.'s Project MAC, in order to make it a more widely available instrument. In addition, work has begun on improving the handling of input-output for the simulation, so as to make the simulation manageable for less experienced users.

An important by-product of the project has been the development of ADMINS, which is now the most sophisticated available computerized file handling system. It was developed by Professor Pool, Stuart D. McIntosh, and David M. Griffel. Currently, it is analyzing a data set of several thousand respondents in a multilevel exploration of Turkish village life and a wide range of material for a study of migration in Boston. It is also processing a subset of education data supporting the Coleman Report, a medical survey by the Joint Center for Urban Studies of M.I.T. and Harvard, sociometric data on the relationship between power and communication, an M.I.T. study of sophomore social science students and first-year graduate students in management science, and a study of the M.I.T. student environment.

Professor Harold R. Isaacs has continued to study the changing perceptions and self-perceptions of people caught up in the large transformations of our time. A major study of the current experience and position of the Chinese in the United States has been undertaken by Dr. Ai-li Chin in association with Professor Isaacs. The form of extensive interviewing has been worked out this past year, using Boston as a pilot area. Dr. Chin's study is focusing especially on generational patterns and family life as they reflect changing identities within both the Chinese and American communities. Professor Isaacs hopes eventually to bring all his explorations of the past several years together in a summarizing examination of the interaction of group identity and political change. Mrs. Chin and her husband Robert Chin, who is Professor of Psychology at Boston University, have also completed a book which examines the evolution of the present, distinctly Chinese approach to psychology, with particular attention to the influence of the Soviet psychology introduced in the early 1950's. It will be published by The M.I.T. Press.

Professors Daniel Lerner of M.I.T. and Morton Gorden of the University of Pennsylvania have finished a manuscript, to be published by The M.I.T. Press, based on their analysis of a ten-year panel survey of opinion among French, German, and British elites on a range of issues centering on national security, prestige, and prosperity and the significance of European transnational institutions. The analysis utilized data from more than 4,000 interviews to study the Europeans' own feelings about their search for new political perspectives in a world dominated
by the two superpowers. The authors examine the conflicts between the elites' assumptions and their preferences with regard to relationships among the three traditional world powers and with the United States.

STUDIES IN MILITARY AND FOREIGN POLICY

Professor Lincoln P. Bloomfield and Amelia C. Leiss have completed the design phase of an intensive examination of United States policy toward local conflicts in developing regions. In the design study, they sought to investigate the problems of local conflict control systematically in order that research and policy priorities could be seen more clearly. They have turned this work into a book entitled *Controlling Small Wars: A Strategy for the 'Seventies*, which will be published in February by Alfred A. Knopf. In the book, they analyze the strategic impact of limited local wars on American foreign policy in an age of nuclear powers and suggest how these wars might be better prevented or terminated. They explain the model they have developed to identify phases in the life-cycle of conflict, based primarily on the role played by military force. The book concludes with case studies of several of the major local conflicts, internal and interstate, since World War II, showing factors operating within the phases and control measures applicable to them.

Professor Bloomfield has begun to explore how to implement these insights in actual policy decisions, using the political-military gaming techniques developed in past Center research. Two levels of games have been planned: a professional-level series, which will be carried out this year, and, alongside these, an experimental series of games designed to apply more rigorous social science methodology with a view to theory building. The first experimental game, held last spring, successfully applied some innovations in format and design. Professor John D. Steinbruner is directing the experimental games with the help of James L. Foster and Robert Beattie. Lt. Col. Cornelius J. Gearin Jr., USA, is assisting Professor Bloomfield in the project as a whole.

Miss Leiss has launched a research effort to determine how significant changes in the sophistication or quantity of conventional arms affect the present political and military environment of the developing world. Working with her on the project are Geoffrey T. H. Kemp and Lt. Col. Jacob S. Refson, USAF, and Col. Harold E. Fischer, USAF, who are on assignment at the Center as Air Force Research Associates. Mr. Kemp traveled last summer in Africa, the Middle East, and Asia to study defense planning procedures—a matter closely related to prospects for peace and security in these regions. Professor Emile Benoit of Columbia University, with the collaboration of Professor Millikan, has begun a
closely related study on the impact of arms on the economies of the developing countries. Finally, an experimental effort is being made, based on the conflict model and case data developed in the design study, to make policy data about past conflicts more readily available to decision makers dealing with evolving conflicts. The ADMINS system will be used in this experiment, with the counsel of Professor Pool; Robert Beattie is the principal researcher on this portion of the research.

Another aspect of the Center's research, directed by Professor Eugene B. Skolnikoff, concerns the interface between science, technology, and international relations. In his book Science, Technology, and American Foreign Policy, published by The M.I.T. Press, he has explored the ways in which advances in science and technology can alter current political issues both directly and indirectly. He has also examined the types of institutions that could bring competent scientific advice effectively to the policy maker. Professor Skolnikoff is now engaged in additional related studies, one of which will explore the realities of the so-called technology gap between Europe and the United States. Another is examining the long-range meaning of science and technology for relations among nations, with emphasis on the implications for future international organization. Other work in progress includes analysis of international issues associated with oceanography, the political implications of the proliferation of space technology, organizational aspects of U.S. technical assistance efforts, and a study of U.S./French space technology relations. Professors Skolnikoff and Weiner are also exploring possible research on the role of scientific and technological investment in economic development, with particular attention to India.

**STUDIES IN INTERNATIONAL COMMUNISM**

Since the early 1960's when the Center first began to study international communism, under the direction of Professor William E. Griffith, attention has focused on the Sino-Soviet dispute, the interaction of Soviet and Chinese maneuvering with the developments in other Communist parties and states, and the implications of these developments for United States foreign policy. While this purpose remains, the Center has begun this past year to expand the scope of its research in Communist affairs to include radical movements around the world that are not necessarily Marxist-Leninist in ideology, organization, and leadership. This seems a logical and necessary response to the rapid growth of such movements, particularly in the underdeveloped regions of the world, and to the ever-widening differences of strategy and tactics among the Communist parties themselves.
The emergence of pluralism within the Communist world has made the study of international Communist and radical movements both more necessary and, in some respects, more difficult. More information is available than ever before about policy conflicts and other developments within and between Communist parties and states, but the task of collecting and analyzing this material is growing steadily greater and more costly. The Center plans to sustain and develop the project's documentation and filing activity, which is now probably the most extensive at any university in this country or abroad, and will continue to make its collection available to researchers from other institutions.

During the last academic year, the project had four books published by The M.I.T. Press, bringing the number in its series on international communism to 13. An outgrowth of current studies in Latin America was Cuba: Castroism and Communism, 1959-1966, by Dr. Andrés Suárez of the University of Florida, which investigates the complicated and changing relations in recent years between Castro, the Cuban Communist party, the Soviet Union, and Communist China. European Communist parties were discussed in three books. The second volume of Communism in Europe appeared, edited by Professor Griffith, with contributions on Czechoslovakia by Zdeněk Eliáš and Jaromír Netík, on East Germany by Carola Stern, on Norway by Jan Otto Johansen, on Finland by Bengt Matti, and on Sweden by Åke Sparring. Professor John Michael Montias of Yale University wrote on Economic Development in Rumania, a companion volume to a study on contemporary Rumanian history and politics by Professor Stephen Fischer-Galati, published previously. Published early in 1968 was Professor Donald L. M. Blackmer's study of the post-war international politics of the Italian Communist party, Unity in Diversity: Italian Communism and the Communist World. Professor Griffith's four-volume study of the East European Thaw, a comparative analysis of developments in Poland, Hungary, Czechoslovakia, and East Germany between 1953 and 1956, is in its final revision. Dr. Robin A. Remington has also completed a study on the changing Soviet perception of the Warsaw Pact. Research in progress includes work by Professor Uri Ra'anan of M.I.T. and the Fletcher School of Law and Diplomacy on Soviet ideology and policy toward underdeveloped areas, particularly the Middle East and Southeast Asia. In addition, Dr. Ernst Halperin is preparing a manuscript on communism and guerrilla warfare in Latin America.
The thrust of self-examination and renewal initiated last year in the Sloan School was coupled this year to a reassessment of relevance, called for by the compelling problems and challenges with which the times continue to confront our own School, universities generally, and all of society.

We learned much to reassure us in the course of this review of our commitments and competences, both with respect to the propriety of our evolving programs and activities — outlined in this report — and with respect to the School’s ability to respond appropriately to new challenges and opportunities.

Some years ago, when the School dropped the adjective “industrial” from its name, we emphasized that this change marked an extension of new concern, not a reduction of going concern. No more than a hurried scanning of the curriculum content in our teaching programs or of the published output of our faculty’s and students’ research efforts or of the loci of their outside professional activities is required to validate that earlier assertion.

The principles of management, the tools and resources available to management, and the developing technologies of management clearly apply now more than ever to business and industry.

But we can discern as well, in this review of our teaching, research, and the other professional activities of faculty and students, a growing recognition of and commitment to the transferability of these analytical devices and concepts to a number of fields of application. These include, but also extend beyond the management of industrial enterprise to the management of health services, the management of education, and the management of public and urban affairs.
The urgencies of today's and tomorrow's problems reinforced an already present conviction that our relevance was more broadly based. Early in the year the faculty cooperated in the preparation of four position papers for the School. These outlined where we stood with respect to each of the domains for managerial analysis noted earlier and where we seemed to be heading in our work in industrial management and in the management of education, health services, and public affairs. These papers helped crystallize our individual and group commitments, our plans, our hopes, and our unanswered questions.

The initial formulation and discussions of these position papers have been followed generally by faculty efforts to affect the future course of teaching, research, or professional action in each of the major fields of application. Meetings of faculty with common interests, for example, in the management of education already have generated a three-year research proposal incorporating a related series of faculty and student projects on (a) the impact of technology on educational efforts and on the management of educational resources and (b) the form and timing of higher education. I will describe these and other research efforts in this and other fields more fully later in the report. I use this example here only to illustrate the degree of our commitment to carrying forward our evolution toward a school of management in the fullest sense.

We have also witnessed this year what is almost an inevitable accompaniment to our confidence in the transferability of our analytical core across a variety of fields of application and in its relevance to the solution of problems in a wide variety of complex organizations. I refer to the sharpening in the definition of that core of management analysis itself. The Sloan School has, of course, always built upon strong disciplines and general functional bases of thought. These have never been isolated from the problems and action areas to which they were addressed or which called them forth. In the recent years, however, as we have continued to tap the strengths of these disciplines and functional roots and to bring these to bear on the newly compelling problem clusters, it is clear that a new confidence is emerging. What we find underscored is a confidence in the evolving unities and synergisms of our disciplines and functionally based tools and concepts in management. The challenges of these complex management problems frequently have attracted flexible faculty groupings drawn from many disciplines and embodying many functional skills. In turn, we have found developing and have encouraged a new integrative thrust of disciplinary and functional foci in our teaching and research programs. To illustrate this second thrust, I need only point to what I feel is a significant advance in curriculum development in in-
formation and decision systems. Here a faculty drawn from individual bases in management information and control, marketing, finance, and operations management have evolved a new and synthesizing focus on the ubiquitous managerial challenge of developing appropriate information systems and in relating significant functional decisions to such systems.

What is most significant is that neither of these unifying thrusts has come at the expense of excellence in our fundamental disciplinary or functional fields. Quite the contrary. Addressing ourselves to the applicability of our analytical capacities to a variety of problems and to the challenge of relating more effectively these distinctive disciplines has helped us to identify weaknesses and to spot gaps in our spectrum of talent and skills.

Indeed, it becomes increasingly clear that the search for relevant excellence in each segment of commitment to teaching, research, and public service reinforces excellence in the others. The following review of our activities and of our attainments this year in each of these segments — our curricular discipline and functional areas comprising our teaching programs, our research accomplishments and plans, and our consulting and other action or professional activities — gives ample evidence of this compatibility.

THE TEACHING PROGRAMS

Teaching activity in the School, measured in subjects, has roughly doubled since 1959-60. Enrollment in management subjects by M.I.T. students outside the Sloan School continues to increase. Program enrollments, representing the total number of students enrolled in respective Sloan School programs, regardless of number of subjects taken, have again shown moderate and controlled increases. Enrollments in the Executive Development Programs have remained steady at previously established admission levels.

Future growth of total enrollment in the Sloan School programs is currently planned to increase at a rate not exceeding 3 per cent per year.

Our faculty as described in last year's report traditionally has clustered around disciplinary or functional classifications. We have never been a "program" faculty, in which an individual professor teaches only in the undergraduate or the Master's or the doctoral or the respective Executive Development Programs of the School. This has meant, of course, that the Program Committees charged with evaluating our programs have had exceptionally challenging and demanding tasks. They have continued this year, as in the past, to discharge them with great effectiveness. Both the members of these committees and our program managers have devoted
great skill and substantial time to reviewing and suggesting improvements in our teaching programs. The Master's and Doctoral Program Committees during this past year have carried through extensive reviews of their programs. The Undergraduate Program Committee and the Executive Development Programs Committee have continued to build on the extensive curriculum reviews in which they engaged during the previous year.

THE UNDERGRADUATE PROGRAM

In last year's report I discussed the initial implementation of a new curriculum for Course xv, the Sloan School's undergraduate program. This past year marked the second year of its implementation, with our sophomore and junior classes enrolling in the new subjects. Next year, with coverage extended to seniors, the three-year transient of curriculum introduction will be completed.

The new curriculum rests on a minimal core of four required subjects, followed by several optional career development paths that were expanded during the past year to include five alternatives. The common core subjects are: Introduction to Management, Managerial Economics, Managerial Psychology, and the Business Environment. With the Introduction to Management subject modified during the year to emphasize quantitative analytic methods, the core now stresses the management disciplines of applied mathematics, economics, and psychology, while also providing insights into management of a company's internal operations as well as its environmental interfaces.

The five options available for student selection include three more specialized professional career paths: Behavioral Science in Management, Management Science, and Dynamics of Management Systems (introduced during the past year by Professor Jay W. Forrester). A less specialized General Management option and an individually designed Special Programs alternative are also available.

The new Dynamics of Management Systems program focuses on the structure of organizations and stresses the unifying concepts of feedback processes. Among the subjects developed for this option is a Feedback Dynamics Laboratory, which was offered for the first time this spring. This laboratory subject, in the sophomore year, is open to all students and satisfies the Institute's project laboratory requirement.

An interesting observation on last year's junior class choices is that the class split approximately equally into the several options. With the exception of the Special Programs in Management option, 15 to 20 men were enrolled in each of the other four optional paths. In time, friendly competition among the options may lead to the relative growth of some of the
programs and the decline of others. The multiple-program approach being taken by Course xv permits this flexible responsiveness of the School’s offerings to changing student tastes and needs as well as faculty interests in educational experimentation.

Our undergraduate seniors for the coming year have completed most of the required series of subjects in each option and during their senior year will take special seminars and field studies designed to give the student a comprehensive view of the field and some practical working experience. In the Behavioral Science option this will involve an interpersonal dynamics laboratory and a seminar in research methods, followed by a research practicum for which the students will organize, design, develop, and complete a major research project. In the Management Science area, students will undertake a field study involving research into current literature, field work, and major case studies. In the General Management area, there will be a management laboratory that will also involve field studies and analysis of current management practices.

During the continuing implementation of the new undergraduate curriculum, a number of educational innovations have been tested and adopted. For example, continued “team teaching” has been used in most of the core subjects; the latest example is the new Business Environment subject co-taught by Professors J. Daniel Nyhart, Edward B. Roberts, and William P. Travis. Another timely innovation has been the beginning by Professor Edgar H. Schein of a thorough long-range research program on the educational effectiveness of the undergraduate subjects. These studies hopefully will lead to continuing reevaluation of teaching methods and subject content, with the objectives of redesign and improvement.

One suggestion of the effectiveness of the new undergraduate curriculum is the announced new graduate management program for the Master’s degree which I will describe below. It reflects the same minimal core approach featured in the undergraduate program, as well as modifications of several of the new subjects that had been developed for the undergraduates.

The successes of our revised undergraduate program, however, are not without costs. The undergraduate core subjects in Managerial Psychology, Managerial Economics, and particularly the Introduction to Management have attracted substantial non-Course xv enrollment. It is gratifying to note that these subjects are popular as electives for students in engineering and science, but the sharply increased enrollments have aggravated our staffing problems in these areas. This is a special problem in the Introduction to Management subject, where it is exceptionally
difficult to find the outstanding teaching talents required to make such a subject more than a superficial survey.

THE MASTER'S PROGRAM

Again this year we received more than 600 applications for the Master's Program, in spite of the uncertainty prevalent among undergraduates because of the announcement last winter that there would be no more draft deferments for graduate study. Our total program enrollment remains steady at the planned current level of 200. The quality of entering students also remains high. Degrees granted during the academic year totalled 88, an increase of six over the previous year. Demand for our graduates appears also to have increased: We scheduled 122 company recruiting visits at the Sloan School, compared to 82 the year before. The demand was accompanied by another increase in salary offers, the median for 1968 running approximately $750 per year higher than for 1967. There is no lack of opportunity for our graduates, whose general ability to analyze a situation and find solutions to its problems is still a scarce resource.

Although the number of applications received for the Master's Program is clearly substantial in relation to the total number we admit each year, we have undertaken for the first time an experimental student recruitment program. The reasons for this pilot recruitment run emerged from a review of our admissions procedure and results. We find that we have been receiving applications from a smaller number and variety of schools and programs than we would like. In consequence, about a dozen of our faculty and staff undertook short recruitment visits last fall. The encouraging consequences of these visits were apparent in the improvements we discerned in our study of the applications received for our program next year. We hope next year to continue and to elaborate some of these recruitment procedures and I will comment on these further activities in next year's report.

The Committee on the Master's Program maintained a schedule of frequent meetings during the year to discuss the objectives and design of the Program's curriculum. The School's Policy Committee and other representatives of the program faculty also devoted considerable time to discussing similar questions. As a result, a number of changes in the core curriculum of the Program have been proposed and approved for the coming academic year.

The over-all requirements for the degree — two years of graduate study including, normally, 18 term subjects plus a thesis — remain the same. In general, the changes recommended this year are (a) a reduction
Indicators of Academic Quality
Students Entering Sloan School Master’s Program, 1963-67

<table>
<thead>
<tr>
<th>Academic year</th>
<th>Size of entering class</th>
<th>Class median, percentile score, A.T.G.S.B.*</th>
<th>Class median, undergraduate cumulative average**</th>
</tr>
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<tbody>
<tr>
<td>1963-64</td>
<td>98</td>
<td>N.A.</td>
<td>3.9</td>
</tr>
<tr>
<td>1964-65</td>
<td>88</td>
<td>N.A.</td>
<td>3.8</td>
</tr>
<tr>
<td>1965-66</td>
<td>108</td>
<td>94</td>
<td>3.8</td>
</tr>
<tr>
<td>1966-67</td>
<td>102</td>
<td>95</td>
<td>3.9</td>
</tr>
<tr>
<td>1967-68</td>
<td>106</td>
<td>89</td>
<td>4.0</td>
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</tbody>
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*Admission Test for Graduate Study in Business.
**Cumulative Quality Point Average, $5.0 = A.$

Starting Salaries of Sloan School Master’s Program Graduates
1961-67 (dollars per month)

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<tr>
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</thead>
<tbody>
<tr>
<td>High</td>
<td>930</td>
<td>2000</td>
<td>2000</td>
<td>1250</td>
<td>1055</td>
<td>1350</td>
<td>1250</td>
</tr>
<tr>
<td>Median</td>
<td>660</td>
<td>683</td>
<td>712</td>
<td>750</td>
<td>820</td>
<td>890</td>
<td>958</td>
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<tr>
<td>Low</td>
<td>450</td>
<td>525</td>
<td>490</td>
<td>583</td>
<td>650</td>
<td>650</td>
<td>600</td>
</tr>
</tbody>
</table>

in the number of specifically required “core” subjects and (b) the introduction of a “concentration” requirement. The first of these modifications, that pertaining to the core requirement, will apply only to new students. The second, that pertaining to concentrations of elective subjects, applies also to second-year students insofar as any may wish to organize their study programs around particular concentration options. The changes in question are intended to further two purposes: first, through reduction in the core requirement, to minimize constraints on the student’s freedom to pursue his or her individual interests; second, through development of a wide range of concentration options, to afford maximum opportunity for pursuing those interests in depth.

The new common core requirement, since it is limited to eight term subjects, leaves at least ten additional subjects plus a thesis for student election. The common core includes the following subjects: Economics for Management I and II will cover principles and applications of microeconomics of markets and incomes and of the macroeconomics of em-
ployment and growth and will include additional topics in applied economics, in labor, manpower and economic security issues, and on the relation of technology to the economy in the long run; Human Factors in Management I and II will focus upon an integrated analysis of the diverse issues encountered in dealing with the human element in organizations; Management Information and Decision Systems I and II will be an integration and synthesis of the theory and techniques of financial and cost accounting with emphasis on management uses of information systems for planning, evaluation, and control of various enterprise functions and operations. The managerial functions of financial management, production management, and marketing management will be introduced in the information systems context and their interrelationships will be considered. Decision models to help in understanding and solving these functional problems will be developed and attention will be directed to the design and capabilities of an information system within which these functional interdependencies may be analyzed. Mathematics for Management will be a subject in basic probability and will serve as an introduction to topics in set theory, probability theory, statistical inference and statistical decision theory. Emphasis will include application of probability theory to managerial problems involving decision making under uncertainty. The Managerial Environment will be a newly designed subject aimed at problem finding and at the evaluation of the relevance of the larger external and the more microeconomic internal organization environment for administrative policy and practice.

The ten electives available in a "normal" program obviously make possible as many as three concentrations without overload. It is clear, however, that if students are to make effective choices, the array and the logic of both the core packet and of the post-core subject packets, options, and offerings will have to be presented and described to the School's students more effectively than we have done in the past. In this connection it is worth noting that this year we have introduced an orientation program for incoming students and a comparable program for our second-year students in an effort to provide them with a better overview of the program and with more effective contact with the faculty. At the beginning of the school year we devoted a two-day program to this purpose and at mid-year an additional half day to follow through on a number of issues more appropriately discussed at that time. In a subsequent student evaluation of these orientation activities, both first- and second-year students revealed that the program was very well received and urged its continuation and indeed urged elaboration of the program next year.

The Master's Program Committee, under the chairmanship of Profes-
Professor Arnold E. Amstutz, has continued to examine every aspect of our Master's Program. In this connection Professor Amstutz is directing a fascinating research project. Begun in June, 1967, it has three related goals: (a) to develop and validate a behavioral (process flow simulation) model of university education; (b) to obtain measures of faculty objectives, faculty and staff actions, and student responses associated with the model process; (c) to develop, apply and evaluate administrative procedures designed to communicate discrepancies between faculty objectives and measured results, and obtain concurrence between the desired and actual educational processes.

Progress to date includes: (a) definition of a preliminary model of the Sloan School Master's Program educational process (this model structure has been reviewed with members of the Sloan School faculty and the Master's Program student body and found to be conceptually and operationally satisfactory); (b) generation of data describing the Sloan School Master's Program in terms of faculty objectives, student demographics, knowledge, skills, attitudes, and expectations, and student and faculty perceptions of change attributable to specific Master's Program subjects; (c) development and implementation of a prototype university management information system, currently containing the Master's Program data described above. This system is being used to provide subject and program evaluation measures to the Sloan School faculty and administration.

The proposed project activities in the future include further validation of a current educational process model using the Sloan School environment as an experimental setting, refinement and expansion of this model to encompass other programs and institutions, generation of data required to validate the refined and expanded model, development of a raw data base and a prototype university management information system to encompass a broad range of programs and institutions, development of the basic software to provide flexible access to the data base for retrieval and processing on a remote basis.

This has clearly been an active year in the redesign and evaluation of the Master's Program. The year ahead will give us ample opportunity to continue to look at the program and to determine the effectiveness of the new requirements and of the applicability of our curriculum to the management of health services, education, and public affairs, as well as industry and business.

THE DOCTORAL PROGRAM

Another 15 doctorates awarded in 1967-68 have brought our total to 50. The major fields of the year's candidates again cover a broad range, in-
cluding management information systems, international business, organization studies, policy, marketing, operations management, operations research, R & D management, and statistical decision theory. The majority of these men have accepted academic appointments at schools such as Wharton, Harvard, Southern California, Boston University, Florida, M.I.T., and Manchester Business School in England. Others will be doing research in firms like RAND, Bell Systems Laboratories, Putnam Management, and The Boston Company.

We expect 20 new students in the Doctoral Program in September. Once again we have found it difficult to keep the number of admissions down to our target number — 15. Of the 20, six are coming from our own Master’s Program. Half the group have engineering or science undergraduate degrees; the rest have backgrounds in the arts, economics, psychology, and business. Two-thirds of the candidates have already done some graduate work. The new students have expressed preliminary interest in specializing in a number of different areas: management information systems, management information and control, international business, organization studies, industrial dynamics, operations research, finance, operations management, decision making, and industrial relations.

With the discontinuance of fellowship support for graduate business education by the Ford Foundation after this year and the decrease in funds allotted for graduate fellowships by the government, we have had to look for other sources of support for continuing students and those just accepted for next year. To ease the strain, we have offered research or teaching assistantships for next year to a number of candidates who would ordinarily have received fellowships. The change, while serious from a financial point of view, is not entirely bad; we have wanted to increase the number of candidates who included some teaching experience in their programs here. To help in the transition from student to faculty member, Professor Schein has designed a student-faculty seminar on teaching. Six of our doctoral students registered in the seminar last spring, and others will be expected to take it in later terms.

It is part of the School’s philosophy that a student who has completed a Doctoral Program in the Sloan School of Management must have a strong foundation in the disciplines of economics, behavioral science, and mathematics. We have required our candidates to demonstrate competence in these areas at a level above that required of our Master’s students, and we have offered seminars in these areas for accomplishing this purpose.

Specialization in an applied field is, of course, an important part of
the Program, and it is customary for the student to write his dissertation in the major applied field which he has offered for general examinations.

The Committee on the Ph.D. Program has been considering proposals for changes in the requirements for the degree, with the objective of designing the best possible doctoral program in the general field of management. Faculty in each area of study have tried to describe the optimal curriculum for specialization in their field, and considerable time has been given to discussing the synthesis of these various proposals. It is our hope that the committee, and subsequently the entire faculty, will agree on a program in time to initiate it for the class entering in September, 1969.

In sum, the demand for our Doctoral Program remains strong, with 153 applicants reviewed for 20 first-year places and our program output, measured by degrees granted annually, continues to increase.

THE ALFRED P. SLOAN FELLOWS PROGRAM

The 46 Sloan Fellows who received their Master of Science degree in management on June 7, 1968, were the 30th class of Fellows to be graduated by M.I.T. since the name Alfred P. Sloan became associated with the Program in 1938. It was the 37th group to complete the Program since Professor Erwin Schell first helped to launch this unique experiment in continuing education in 1931.

The Class of 1968 added another “first” to the long record of innovations generated by the Sloan Program. Prague was added as a regularly scheduled visit in the European Management Trip; and 30 of the Fellows invested their long, free weekend to visit Moscow — accompanied by Dean Peter P. Gil, Dean Abraham J. Siegel and Professor Paul H. Cootner. The group met with a number of senior people representing industry, science, the university, and with the U.S. Ambassador and his staff. An important new educational dimension was added to the Sloan year; and perhaps some small contribution was made towards building a productive bridge between the two countries.

The Class of 1968-69 was selected on March 30, 1968. It is the largest class in the history of the program (50); and it was selected from the largest number of applications ever received for any given year. Position levels and salaries are higher and academic records are stronger than ever. It promises to be one of the best classes of Sloan Fellows to benefit from and contribute to the study of management at the Sloan School.

The Class of 1969 boasts the first woman to be selected as a Sloan Fellow. She is Sister Anne M. O’Neil, R.S.C.J., the Assistant Treasurer of Manhattanville College. The Program looks forward with a great deal
of pleasure and pride at the prospect of adding an able woman executive to its list of outstanding alumni.

The new class has a slightly different profile from the Class of 1968: more U.S. corporations, fewer foreign nationals, and fewer representatives of the Federal government. Fourteen organizations are represented for the first time: ALCOA, Deere, EURATOM, First National City Bank (New York), Lennox, Manhattanville College, Northrop, Reynolds Tobacco, Shell, G.E. (of South Africa), Trostel, U.S. Army Materiel, State Department and Yoshitomi Pharmaceuticals.

The School was pleased to have the opportunity of welcoming back into the Program a few organizations that had been absent for two or more years: Canadian Imperial Bank, Creole (Standard Oil of New Jersey), General Motors, and Grumman Aircraft.

The faculty and administration of the Sloan School continue to search for ways of improving the program. A great deal of attention is paid to the reactions of the Fellows, during the year, at the end of the year, and after they have returned to their sponsoring organizations. Some of the more significant changes for the coming year were the result of feedback from the Sloan Fellows.

Under the able direction of Sanford Kaye of the Department of Humanities and Wendell W. Larsen, the summer writing-concepts subject has been developed to the point where it is now viable in terms of substance and presentation. Although experimentation will continue, there is now a successful model of that subject. The Program is grateful to the Chrysler Corporation for making Wendell W. Larsen (a Sloan Fellow last year) available to assist Mr. Kaye in developing and teaching the subject.

A significant block of time will be allocated in the fall term, 1968, to international business. Eight sessions will be offered by Professor Charles P. Kindleberger of the Department of Economics, and eight sessions by Dr. Richard D. Robinson. Out of these efforts will come a clearer picture regarding the emphasis that should be allocated to this area. The commitment of the School to the importance of the area is strong.

Efforts have been made from time to time to interrelate the following subjects into one broad avenue: industrial dynamics, operations management, and management information systems. Another attempt will be made in the fall of 1968, coordinated by Professors Roberts, Donald C. Carroll, Wallace B. S. Crowston, Jay R. Galbraith, and David N. Ness. They will be coordinating their efforts under the new subject title, Information and Decision Systems. The fact that similar efforts are now under way in both the Undergraduate and the Master's Programs, as I
have noted earlier, has helped the development of this curriculum change in the Sloan Fellows Program.

During the past two years a growing number of sessions in the Program have been devoted to urban problems. The year 1968-69 will see a further increase in the amount of time allocated to that increasingly important area.

The accompanying table summarizes some of the vital statistics for this year's and next year's Sloan Fellows Program.

THE PROGRAM FOR SENIOR EXECUTIVES

The number of applications for places in the Senior Program continues to increase. Although the demand from U.S. corporations is stronger each year, the interest from non-U.S. corporations is even greater. The selection of participants can be more and more rigorous, but that blessing carries with it the awkwardness of having to reject, or at least postpone, a larger number of qualified applicants. It is a sensitive market.

The Seniors who attended the sessions of fall, 1967, and spring, 1968, represented ten countries, 27 industries and 47 companies. One-third of the men had advanced degrees; five of these were doctorates.

The spring, 1968, session was the 25th session conducted by the Sloan School since the program was established in 1956.

The type of man who attends the program is somewhat different from the typical participant in the fifties and early sixties. He is generally a university graduate, and it is increasingly common for him to hold a Master's or a doctoral degree — usually in a technical field. Men who hold senior management positions in research and development are attending in greater numbers and the positions held by these men tend to be more senior. As the job level held by the participants rises and their educational backgrounds become more sophisticated, their expectations can be expected to grow. This will put an increasing amount of responsibility on the faculty to offer more challenging material. At the same time, it can be predicted that a higher quality participant will permit the faculty to go deeper and further in their disciplines — a situation that usually provides greater stimulation and satisfaction to all who come in contact with this demanding activity in the area of continuing education.

Some summary statistics for this year's Senior Executive classes are displayed in the following table.

GREATER BOSTON EXECUTIVE PROGRAM

The Greater Boston Executive Program, now more than ten years old, continues to flourish and it points to the kind of cooperation that is possi-
### Alfred P. Sloan Fellows Program

<table>
<thead>
<tr>
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<th>Current year 1967-68</th>
<th>Next year 1968-69</th>
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<tbody>
<tr>
<td>Enrollment</td>
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<tr>
<td>Age range of Fellows</td>
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<td>36.8 years</td>
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<td>Fellows with Master's degrees</td>
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<td>47</td>
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<td>Industries represented</td>
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<td>Foreign countries represented</td>
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<tr>
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<td></td>
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<td>Canadian, French,</td>
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<tr>
<td></td>
<td>Japanese, Norwegian,</td>
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<td></td>
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<td>South African,</td>
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<tr>
<td></td>
<td>Yugoslavian</td>
<td>Venezuelan</td>
</tr>
</tbody>
</table>
able between a university and the business community. The Program is still administered by a small committee of Boston business executives. Members of that committee recruit and select the participants; they also collect and disburse funds, publish the brochures and application forms, and so on. The program virtually runs itself; arrangements with faculty are made informally by the Boston Committee and coordinated by Dean Gil.

Twenty-five participants completed the Program in May, 1968; they represented 20 companies in the Greater Boston area. There are now more than 250 alumni of the Program. When their alumni organization holds a reunion each year, well over 50 per cent return to attend special seminars and listen to a principal speaker after dinner.

Through the members of the Boston Committee and the participants in the course, the Sloan School has been brought into close contact with a wide variety of business activities in its own community. The interest of that community in management education at the Sloan School is stronger than ever. It is satisfying to know that such interests can be met, at least in part, by the Sloan School and the community working together.

**SUMMER PROGRAMS AND INDUSTRIAL LIAISON PROGRAMS**

Throughout the year and particularly during the Institute's Summer Session, M.I.T. offers a series of intensive programs that review current trends and introduce new ideas and approaches in many of the fields in which degree programs are offered.

The Sloan School again played an important role in supporting this process of continuing education afforded by M.I.T.'s Summer Session. Professors Forrester, Roberts, and Willard R. Fey, with Alexander L. Pugh III, Carl V. Swanson, and other members of the industrial dynamics group of the School, offered their program in Industrial Dynamics in which each participant had the opportunity to build his own dynamic model of the interrelated flows of information, orders, capital equipment, material, money, and manpower and test it on M.I.T.'s on-line time-sharing computer system. For the fifth consecutive year Professor Zenon S. Zannetos and James C. Emery (of the Wharton School of Finance and Commerce at the University of Pennsylvania) offered their two-week program, Concepts of Management Planning and Control Systems: Theory and Technology. A third special summer program, Computer Simulation of Market and Competitor Response, was offered under the direction of Professor Amstutz. Lecturers for this program, designed to familiarize executives with procedures and techniques used to develop, validate, and implement computer-based microanalytic market simulations, included Professors Peer O. Soelberg, John D. C.
<table>
<thead>
<tr>
<th></th>
<th>Fall 1967</th>
<th>Spring 1968</th>
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<tbody>
<tr>
<td>Enrollment</td>
<td>27</td>
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<tr>
<td>Age range of Senior Executives</td>
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<tr>
<td>Average age of Senior Executives</td>
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<td>Senior Executives with doctorates</td>
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<tr>
<td>Companies and organizations represented</td>
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<td>25</td>
</tr>
<tr>
<td>Industries represented</td>
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<tr>
<td>Foreign countries represented</td>
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<td>7</td>
</tr>
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<td>Number of foreign Senior Executives</td>
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<td>12</td>
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<tr>
<td>Nationalities</td>
<td>American, Italian, British, Canadian</td>
<td>American, British, Australian, Danish, Swiss, Chilean, Canadian, Dutch</td>
</tr>
</tbody>
</table>
Little, Carroll, David B. Montgomery, Christopher R. Sprague, and Professor Henry J. Claycamp of Stanford University. Professor Little directed a fourth two-week program on Marketing Information Systems, which dealt with topics like the marketing manager's problems, marketing measurements, data bank and data retrieval, marketing models and simulation, on-line use of models, and implementation of existing systems. Lecturers in this program included Professor Amstutz and outside speakers active in the area. Professors Montgomery and Glen L. Urban directed their own program on Management Science in Marketing, in which they presented recent advances in the application of management science to marketing. Professors Roberts and Donald G. Marquis, with Professors Thomas J. Allen, George F. Farris, William H. Gruber, and Irwin M. Rubin and other members of the research program on the management of science and technology in the Sloan School, offered for the fifth year a program on the Management of Research and Development. Finally, faculty members from the School participated in a program on Operations Research in Public Systems which was presented by the staff of M.I.T.'s Operations Research Center.

In addition to our participation in these valuable Summer Session programs, which afford the participants a stimulating intellectual and professional experience, the Industrial Liaison Office of the Institute presents a number of symposia during the year for participating corporations. In November, 1967, as part of M.I.T.'s 1967-68 Industrial Liaison programs, Sloan School Professors Marquis, Allen, Gruber, Roberts and Rubin presented the symposium, "Management of Research and Development." In May, 1968, Professor Cootner chaired the symposium, "Corporate Financial Management." These programs, too, continued to draw impressive recognition from sponsoring corporations.

TEACHING PROGRAMS: POSSIBLE FUTURE DEVELOPMENTS

This summary of the School's teaching programs and activities reflects a full and varied set. It is clear, however, that despite the diversity in program objectives and the variety of intended audiences, there remain many excluded elements.

Over the years there have been signs and pressures to which we have responded in piecemeal fashion. Special students, for example, have been permitted to register for one or two subjects in our degree programs when it was clear that the students' backgrounds and qualifications assured successful participation in these subjects. These special students typically have enrolled for post-baccalaureate study with clearly defined
and limited objectives but not as applicants for degrees. Steady but grow-
ing pressures have prompted us to extend our “special” categories in
order to accommodate an increasing number of potential students whose
needs do not fit precisely or even closely those which we seek to meet in
our degree programs or our other Executive Development Programs. We
have continued to invite a very limited number of special faculty or in-
dustrial fellows to spend an entire year with us in the pursuit of a custom-
tailored program of subjects, projects, and research. We have also com-
mitted ourselves to the development and presentation of our first pro-
gram for urban executives in an effort to meet the needs for extended
managerial training of prominent and permanent functionaries in city
government.

These are but some of the devices already designed to accommodate
a variety of students in continuing education over a lifetime of work
and learning.

It is clear that during the next few years the School will have to con-
sider other new options and possibilities in our teaching programs.
These include a possible “entrepreneurship” option or program for un-
dergraduates that might build upon or emanate from the self-learning
experience which the Undergraduate Systems Program now affords a
limited number of our undergraduates. It may emerge from a revamped
Special Program option which I have mentioned in my earlier discussion
of our undergraduate programs. In addition, it is quite clear that the
School may be obliged to consider a revised sequence in management,
perhaps of one year’s duration, which would be aimed at non-Course xv
undergraduates at M.I.T. Larger and larger numbers of such science and
engineering majors at the Institute have been searching clearly for such
a sequence during recent years.

Finally, we may need to consider fashioning the equivalent of an
Engineer degree (one-year post-Master’s degree) in management for
those students who want more than the Master’s degree but not a do-
ctorate. The increasingly visible returns from this sort of additional inves-
tment in education have tended to increase the pressures from students
for this sort of alternative.

In the face of such proliferating possible program menus, it is clear
that the future will oblige us to continue to evaluate and to improve exist-
ing programs and to fashion new ones. It is equally clear, however, that
in the face of resource constraints it may present us with the need to make
choices concerning priorities in the allocation of scarce educational re-
sources. This challenge should be a fascinating exercise in the manage-
ment of our own organizational complexities.
There is no disputing the relation between research and the relevance of the teaching and action programs in which our faculty and students are engaged. Any progress we make along these other major axes of our professional lives rests on the knowledge which research creates.

Our School remains strong because our faculty and our students are dedicated to building their professional lives upon a research-based foundation. The interactions and avenues of intersection here are complex and the flows move from problems to research, from research findings to applications, and from both to a more vital teaching curriculum.

I can list here only the outlines of some of the major research interests and activities of our School. Only an exposure extending over a period of months—to the many-faceted thrusts after new knowledge and the manifold efforts to test and refine that new knowledge in the crucible of applications—could capture the flavor of our research activities and discern the key role management research plays in the totality of our professional concerns.

My reporting here is grouped by discipline and functional classification. In concluding this section, I shall point to several of the integrating themes and fields of application that cut across these necessarily arbitrary divisions I use now to describe our faculty's research efforts.

THE HUMAN FACTORS IN MANAGEMENT

Studies in organizational behavior, in the management of science and technology, and in industrial relations constitute a wide and important band of research activity at the School.

ORGANIZATION STUDIES Professor Farris studied the interrelationship between leadership behavior and group performance. Dr. Gil began an analysis of the fundamental differences between the reactions of behavioral scientists and the reactions of business managers in the study and resolution of human problems in an organization. Professor Mason Haire has continued his work in the development of a computerized model of the movement of personnel through a firm over a period of time. This model of manpower planning is currently being operationalized in two firms. Professor David A. Kolb continues his interest in personal growth and change. During the past year he has designed a series of experiments aimed at isolating the types of feedback and group climate which maximize the possibility of constructive personality change and group effectiveness. In addition, he has concluded a number of studies of self-directed change and has sought to relate differences in styles of in-
formation usage to personal motivational styles. Professor Leo B. Moore continues his interest in the management of improvement and in the relations of integrated administrative policy to organizational effectiveness. Professor Rubin is concluding his study of the M.I.T. Fellows in Africa and in Latin America, which focuses on the substance of their contributions, on the processes through which the contributions were made, and on the changes in the attitudes, values and goals of the Fellows. James A. F. Stoner assisted Professor Rubin in this study and has worked by himself on a series of experimental studies on individual and group risk-taking behavior with emphasis on the relation of widely held values and perceived relative riskiness in decision making. Professor Schein continued his examination of the influence of organizations on the beliefs, values and attitudes of the incoming manager and of the effect of such influence on the productivity, creativity and growth of the manager over time.

MANAGEMENT OF SCIENCE AND TECHNOLOGY The second major effort in the organization studies area is centered in the group's research program on the organization and management of science and technology, directed by Professors Marquis and Roberts and supported by grants from the National Aeronautics and Space Administration and other sources. Professor Allen continued his investigations of information sources and flows in research and development organizations. In this context he studied information flows among small research groups actively engaged in advancing the state of the art of fluidics technology and has continued earlier studies tracing the flow of information within industrial R & D laboratories with an eye to identifying impediments to efficient communication flow as well as means for improving the process. Professor Allen has also studied the protocols of the problem-solving process in systems research and development and has investigated the factors influencing relative user costs of technical information channels. Professor Farris has studied the motivation of research and development personnel. Professor Marquis, with Professor Gruber, convened an interdisciplinary group of social scientists, physical scientists and engineers in order to study the human factor in the transfer of technology. With Professor Rubin, Professor Marquis has continued his analysis of factors in the performance of large government research and development contracts in 50 industrial laboratories. In addition, he has studied the criteria for research project selection in commercial laboratories and the outcome of these projects and has also studied the tendency to choose risky decisions as a function of the degree of uncertainty and as modified in group decision conferences. Professor Roberts continues his analysis of the factors
influencing government awards of research and development contracts and the extent of conflict between these practices and government objectives. He has also studied the factors affecting the generation and use of ideas for new products and the impediments to the realization of those technical ideas which remain untapped.

INDUSTRIAL RELATIONS The staff of the Industrial Relations Section of the School, long before the contemporary hue and cry, was involved in the manpower aspects of urban problems, and during 1967-68 it has continued this research involvement. Professor David P. Taylor, with the assistance of Professor Francis M. McLaughlin (on leave from Boston College), completed the second year of research on the Kendall Square Urban Renewal Project. This study, financed by a grant from the Ford Foundation, seeks to identify the employment experience of a panel of workers displaced by urban renewal activity. With Professor Michael J. Piore of the Department of Economics, Professor Taylor is also examining the relative efficiency of public subsidized on-the-job training programs and of private efforts in the same industry, occupation, and geographical location. Professors Piore and Taylor are also involved in separate but related studies of Federal and local manpower programs in the Boston area. Professor Siegel has studied municipal management and employment relations in the city and is examining, with Professor Arnold Weber of the University of Chicago, the impact of unions and collective bargaining on the nature and quality of municipal labor relations and public administration. Other research activities of the Section focus on the impact of computers on management and on collective bargaining. Professor Charles A. Myers continues his study of the effect of new computer introductions on the organizational structure of the firm, the nature of managerial jobs affected, the reaction of the affected managers and the distribution of managerial functions. Professor Siegel has just sent to The M.I.T. Press a series of studies examining the impact of computers on trade unions' and management's policies and practices concerning collective bargaining. The volume is based on a small research conference convened at M.I.T. this spring by the Section in collaboration with the American Arbitration Association. Professor Douglass V. Brown has been working on a study of legalism and industrial relations in the United States and will continue this study in the coming year. Professor Taylor has also completed an earlier study of the training and placement of older workers in Boston and has begun work with Professor Joseph C. Ullman at Purdue University on a study of the job-seeking activity of Master's graduates in management.
ECONOMICS

Professor Gruber continued his studies of the impact of research and development on the U.S. economy. The development of a large-scale macroeconomic model of the U.S. economy, to be used for policy and forecasting purposes in connection with quarterly movements of output and production, continues to occupy a good portion of Professor Edwin Kuh's research time. Professor Paul W. MacAvoy concluded a study on the economic evaluation of alternative development schemes for fast breeder reactors. This project seeks to evaluate the schemes in terms of predicted returns to society for each dollar of research expenditure and includes findings on which companies are most efficient, given presently available information on research costs and the cost of and demand for advanced reactors. In addition, Professor MacAvoy investigated the costs and benefits of large-scale Federal research on nuclear desalting. Richard Schmalensee, with Professor MacAvoy, developed a computer-based oligopolistic industry model that permits students to play the part of the oligopolist. This Game on Logistics of Operating in an Oligopoly Market (GLOOM) has been used effectively in our economics seminars. Professor Zannetos continued his investigation of the factors that affect the supply and demand of tank ship services and the development of the theory of price formation in the oil tank ship market. Professor Sidney S. Alexander was on leave during the year and was engaged in full-time basic research on the economics, sociology, and politics of the Middle East as participant in a project under contract with RAND and the Ford Foundation.

FINANCE

The research interests of the finance faculty continue to be active and productive. Professor Cootner extended his study of the theory and practice of commodity hedging and its interplay with speculative activity. Professor Cootner has focused on the relationships between prices of cash commodities and futures and the relationship between prices of different futures. In addition, Professor Cootner has examined the problem of optimum portfolio policy and asset maturity. His interests here are analogous to his earlier concerns with commodity hedging decisions. Professor Donald E. Farrar concluded an empirical analysis of financial decision making in the firm and also studied operational approaches to portfolio management by employing multivariate statistical techniques to stratify securities into operationally identifiable classes on which subsequent evaluation and portfolio selection models could be based. Professor Daniel M. Holland has studied the effects of taxation on the level, quality, and direction of effort of top corporate executives and has also examined...
the relation of tax policy to the nature of the jobs which executives choose. Professor Miles Kennedy examined the net effects of differences in depreciation policies by simulating asset portfolios of varying age patterns. Professor Stewart C. Myers investigated the effects of uncertainty on corporate security valuation and in another study examined the relative profitability of conglomerate and other types of mergers. Professor Gerald A. Pogue developed an intertemporal portfolio management model. Professor Travis continued his studies of a theory of factorial trade incorporating the general theories of exchange, of international trade, and of the firm. Professor Franco Modigliani, while on leave, continued his research on the M.I.T.-Federal Reserve Bank model of the American economy and the parallel model of the Italian economy.

QUANTITATIVE METHODS
As in the past, the work in the quantitative methods area has been concerned this year with development of quantitative techniques that could be coupled to the research, teaching, and service interests of all members of our faculty. This year Professor Alexander devised a program for proving theorems on the basis of an arbitrary set of postulates. Professor G. Anthony Gorry continued his research on models of diagnosis for use in an interactive computer program. Professor Gorry, with Professor Jeremy F. Shapiro, has also developed new algorithms for the integer programming problem through the use of algebraic group theory. Professor Gordon M. Kaufman has continued his research on problems of estimation and inference by Bayesian methods and in addition has, with Professor Roy Penchansky of Michigan, developed a stochastic model of the behavior of the economic reserves of a union health and welfare fund and of policy choices by fund trustees. Professor Kennedy has developed a simple computer program for project risk evaluation. Professor Little has continued work on his investigation of methods for synchronizing traffic signals in a network so as to maximize system performance. Professor Shapiro has examined turnpike planning horizon problems for multistage models. Professor Sprague has continued his search for imaginative ways for the computation administrator to use his own resources effectively. Professor Leon S. White has developed computer aids for teaching managerial mathematics, statistical decision theory, and other quantitative techniques.

INFORMATION AND DECISION SYSTEMS
The research output of the School in the areas of management information and control systems, industrial dynamics, marketing, and the management of operations continues to be high.
MANAGEMENT INFORMATION AND CONTROL SYSTEMS  In the management information and control systems area, Professor Amstutz has continued his investigations of the use of automated information monitor and review techniques by operating management. Professor Michael S. Scott Morton has experimented with the design and use of an interactive visual display system for management and has also developed a terminal costing system that permits the senior manager to build specific costs for particular decision situations into his models. Professors Zannetos and Scott Morton have continued their analyses of cost effectiveness models and the sensitivity of management decisions and have embarked upon a three-year research project in learning processes in an effort to devise a system for associating and integrating knowledge. Professor Zannetos has continued his investigation of associative information systems in the domain of managerial controls as well.

INDUSTRIAL DYNAMICS  Professor Forrester and his colleagues in the industrial dynamics group continue their research on the development and application of industrial dynamics models. Professor Forrester has examined the growth dynamics of a new corporation and at the end of the year had begun a fascinating application of his feedback systems models to questions on the growth and stagnation of cities. Professor Roberts has developed industrial dynamics models to explain the causes of growth fluctuation and decline of effectiveness of research and development laboratories and has developed a series of feedback systems models aimed at demonstrating the applicability of industrial dynamics to a wide variety of human interaction problems. Professor Carl V. Swanson has continued his efforts to provide a framework to guide the analysis of simulation models of complex feedback processes found in managerial and social situations and has paid particular attention this year to the interactions between resource management and the market in the process of corporate growth. Mr. Pugh has continued development of the Dynamo II computer program for compiling equations that describe industrial models.

MARKETING  This year Professor Amstutz has been active in investigating the use of large-scale simulations of competitive marketing activity as aids in short- and long-term planning and has also improved a series of complex simulation models of marketing behavior to take better account of the activities of actual customers. Professor Amstutz has also developed a new comprehensive teaching device that will give students more realistic and broad marketing experience. Professor Little has been studying the adaptive control of marketing variables and has investigated
methods for determining advertising media schedules by mathematical programming. In addition, he has constructed a mathematical model for evaluating the effect of the distance between customer and dealer on the sale of automobiles and the model is currently being set up on a time-shared computer to enable rapid evaluation of proposed dealer sites. Professor Montgomery continued his research on non-linear estimation of market response and on the social psychological variables affecting consumer behavior and consumer decisions. Professor Urban continues his studies on new product and product line decisions and on optimum marketing mix.

MANAGEMENT OF OPERATIONS Finally, in this general domain of information and decision systems, the operations management group has once again had a productive research year. Professor Carroll continued his investigation of the potential of on-line simulation in real-time system management. He has also developed a management game for students of production management. Professor Crowston studied the interaction between operating models of the firm and facilities design models that focused on problems in plant location facility layout and capacity addition. He also has developed heuristic and programming techniques to assist in the design, planning, and control of projects. Professor Galbraith explored techniques for coordinating flows of work between functionally organized departments and continued his research in the motivational determinants of job performance and on the influence of an organization's technology on the structure of the organization. Herbert F. Goodwin continues his work on the implementation of industrial improvement. Professor Moore studied the practice and techniques used in standardization programs. Professor John F. Pierce Jr. developed his work on constructing mathematical models for carrier dispatching, box car loading, and cutting stock problems. Professor John F. Rockart has proceeded with his investigation of the effectiveness of the current scheduling process in a hospital outpatient department and has undertaken an investigation of the scheduling of patients through a medical clinic. Professor White analyzed the description, design, and control of flow shop manufacturing systems with an emphasis on the relation between production scheduling, inventory control, quality control, and equipment maintenance.

THE MANAGERIAL ENVIRONMENT, POLICY, AND OTHER RESEARCH
In addition to the research mentioned in the major subheads above, the School's faculty conducted research in a number of topics involving the
managerial environment and policy. Professor Michael J. Brower concluded a study on United States business in Colombia and also studied U.S. government policy making on atomic energy, 1940-1945. Professor Nyhart continued his evaluation of the experience and problems of many of the world's development banks and has continued his program for training staffs of 20 banks in the Brazilian National Development Banking system to increase the effectiveness of that bank's organization. Research on human and organizational changes and the technical assistance relationship of the program is also being conducted. Professor Roberts continues his studies on the formation and growth of new technical enterprises and on the nature of entrepreneurship within the large corporation for stimulating R & D utilization. Mr. Robinson has continued his studies of private U.S. firms and state enterprise abroad and has sought to evaluate the success of these joint ventures. Professor Thomas M. Hill has examined the institution building process from the vantage point of his experience with the Indian Institute of Management at Calcutta.

Growing recognition of the transferability of our core analytical concepts to a number of fields of application is revealed clearly in this partial array of our faculty interests. It is evident that the largest portion of our School's research effort is still focused on problems deriving from industrial management, but in the last few years our exploratory probes have scanned beyond the already wide stretch of this industrial management horizon.

Last year almost a third of our faculty was doing some teaching or research in one or another aspect of managing public affairs. In this field of interest, as in industrial management, there is great variety in the work done. Some examples from the group enumeration above and some additional items not noted above are: research on the management of a judicial system; summer studies on applying business technology to urban problems; a systems analysis of city management and regional economic growth; participation in a Boston harbor research project; research on helping relations in the ghettos and on traffic control problems in the suburbs; an industrial dynamics analysis of the processes of urban growth and stagnation; studies on the automobile and the management of its accompanying air pollution; labor market and employment relations studies based in the public sector; economic studies of municipal finance, new towns and land banks; and even studies on the effectiveness of cost effectiveness studies in the public sector.

In the management of health services field, our current research has also been gaining momentum, although to date our efforts have involved principally an emphasis on the potential impact of computer technology
on the management of health services. The work done this past year on
the uses of the computer in the organization of a hospital, on computer-
aided diagnosis, on scheduling in a group medical practice and on com-
puter-assisted scheduling in a hospital outpatient department, the simula-
tions run on the organizational aspects of the Harvard prepayment plan,
and the proposed work with the National Institutes of Health in research
management are all examples of this new thrust in our research interests.

Finally, this roster of research in the School reflects the fact that a part
of our faculty has tackled the appraisal of two central aspects of the man-
agement of higher education: (a) the impact of technology on educa-
tional efforts and on the management of educational resources, and (b)
the form and timing of higher education. These two areas of inquiry are
obviously mutually interdependent and have brought together individuals
from the management information and control systems areas and from
the organizational studies group. A coordinating committee consisting of
Professors Charles A. Myers, Schein, Zannetos and Scott Morton has
prepared an integrated research proposal for continuing studies in these
two areas and we anticipate that a firm base can be set down for further
work in the management of education, once funding is obtained for these
studies.

INTERNATIONAL PROGRAMS

During the past year the School has continued to sustain its international
perspective, but as I indicated in earlier reports, we have recently been
engaged less in “institution building” and more in informal collaboration,
research programs, and curriculum development. For example, the
School’s association with the Indian Institute of Management in Calcutta
continues, but our responsibility for the assignment of full-time faculty
has ended and our own faculty currently participate in the Institute’s
program development and ongoing research on the basis of visiting pro-
fessorships. The interests and the work of individual faculty are reflected
in the preceding review of major research themes which the faculty
probed during the year.

INDIAN INSTITUTE OF MANAGEMENT, CALCUTTA

I am pleased to report that the Indian Institute of Management, Calcutta
(I.I.M.C.), which the Sloan School helped to establish, now in its seventh
year of operation clearly has reached a stage of development at which it
no longer requires the formal support of the Sloan School. As of January
1, 1968, all financial responsibility under Ford Foundation grants in sup-
port of the Calcutta Institute was transferred to that institution, and
agreement was reached with I.I.M.C. to end the formal interinstitutional
affiliation as of June 30, 1969. An intensive and promising effort is now being made to develop collaborative research activities as a basis for a continuing and constructive relationship between the two schools.

Thirty representatives of the Sloan School, including two M.I.T. doctoral students and five professors from other American university faculties, have now visited India on behalf of I.I.M.C., 16 of these for periods of an academic year or longer. I.I.M.C. visitors to M.I.T. have been fewer in number — a total of six, with only three staying for as long as nine months — partly because that faculty is smaller, but also because many of its members had previously studied in the United States.

From the Indian standpoint, the results of this exchange have been tangible and, I believe, satisfactory. Nearly 200 carefully selected students have now completed long-term study programs at I.I.M.C. and have been well placed to begin either managerial or academic careers. Also, more than 700 practicing managers have attended a variety of short-term executive programs at the Institute. At this point, despite grave handicaps of inadequate physical facilities, local political instabilities, and changes in leadership, the Calcutta Institute is clearly well established, offers professional education of high quality, and shows considerable promise in respect to research capability.

From the American standpoint, the benefits have been less tangible but nonetheless real. Through this experience, the Sloan School faculty has certainly enlarged its understanding of economic development problems, and may thus have enhanced its capacity to contribute to the resolution of them significantly. The principal benefits to this School may well be ahead if we succeed in effectively utilizing the association with I.I.M.C. as a major research resource.

LONDON GRADUATE SCHOOL OF BUSINESS STUDIES
The Sloan School continues its cooperation with the London Graduate School of Business Studies in two principal ways. First, we have continued to work with Charles Handy in planning the London Graduate School's own version of a Sloan Fellows Program which they intend to begin this year. Second, we have made plans for the visits of a number of our own faculty to the London Graduate School and trust that these short stays will continue to build effective bridges between the two schools and to extend the good feelings and cooperative personal relations which have marked the ongoing contacts between us.

M.I.T. FELLOWS IN AFRICA AND COLOMBIA
The M.I.T. Fellows in Africa Program afforded 63 young men, some with families, the opportunity to spend two years each on assignment in 12
countries in Africa during the 1963 to 1967 period. The Fellows occupied many responsible positions in government and provided important technical assistance to the ministry heads with whom they worked. The Program was always intended as a temporary program of technical assistance and as a unique educational experience. The M.I.T. Fellows in Colombia Program, a smaller program modeled on the Fellows in Africa experience, concluded this year and thus brings to full termination our "action" efforts in these educational programs abroad. We all have an intuitive feeling that the beneficiaries of the programs were many. The ministries and the organizations in Africa and in Colombia within which our Fellows made important and useful applications of their managerial training clearly benefited from these efforts. Perhaps more important, the Fellows themselves profited enormously from their experience of working effectively in complex organizations based in foreign cultures. As I indicated in my last report, however, we felt that these intuitive evaluations should be buttressed by more careful analysis and toward this end Professor Rubin has continued to study critically the experiences of these M.I.T. Fellows. During the past year Professor Rubin has completed the analysis of extensive questionnaire data which he and his colleagues have collected from more than 50 M.I.T. Fellows in Africa alumni and from 30 wives who accompanied their husbands to Africa. There have been more than 65 in-depth personal interviews conducted with both M.I.T. Fellows and their wives. In addition, Professor Rubin has now completed the longitudinal study which he had earlier undertaken of the M.I.T. Fellows in Colombia. Finally, a series of seminars attended by the Fellows and their wives provided effective sounding boards for the initial presentation of the results of this study. A published manuscript should be available sometime next year. It is not premature, however, at this juncture of final termination of a unique educational experience to express appreciation to Professor Carroll L. Wilson, to Constantine B. Simonides, now Assistant to President Howard Johnson at M.I.T., and to President Johnson for their important roles in the inception, evolution, and history of the African and Colombian Programs.

**BRAZILIAN DEVELOPMENT BANKING PROJECT**

In pursuit of its interest in forwarding management education on a broad front, the Sloan School successfully completed the first year of this project, aimed at improving the human and institutional resources in Brazil's 20-bank development finance system. Brazil’s National Bank for Economic Development (B.N.D.E.) is cooperating. The project is supported by a Ford Foundation grant.
The principal objective is the design and implementation of a working
information and control system operating within and between the three
levels of organizations: B.N.D.E., the state level development banks
through which B.N.D.E. provides medium-term credit to enterprises,
and the enterprises themselves. An organizational development program
seeking to improve the corresponding institutional structure is a com-
plementary objective.

To these ends, much effort during the past year was focused on the
establishment of a basic course for staff members of development banks
located throughout the country. The first seven-week course, which began
in January, 1968, emphasized practical managerial concepts. The con-
tinuing propagation of these concepts is going on through direct work of
B.N.D.E. teams with the state banks and their borrowers.

The M.I.T. component in Brazil is composed of a full-time senior
representative, Heinz E. Luzny, who joined the project from the Interna-
tional Finance Corporation, an affiliate of the World Bank. Mr. Luzny
will be joined in a few months by D. Anthony Butterfield, who is com-
pleting his doctoral work in psychology at the University of Michigan.
Their collaborators include a director and officers of B.N.D.E. responsi-
ble for the development of the multi-institutional system and for
B.N.D.E.'s training effort. In addition, Professors Nyhart (M.I.T. Proj-
ect Coordinator), Farris, and Rockart of the Sloan School provide over-
all direction and backup support. Work on preparation of teaching
materials — text, manual, case material, development banking game, and
so on — begun last summer, is continuing this year at the Sloan School,
with the help of seven research assistants.

The project also includes research on the process of transferring tech-
nology. To this end, benchmark data were collected last July, measuring
attitudes of directors and staff in four of the 20 banks. The analysis of
this research helped to shape the training course and subsequent pro-
gramming.

**VISITING INTERNATIONAL FELLOWS**

As in past years, several visitors from other parts of the world have spent
the year with us, representing Czechoslovakia, England, India and Yugo-
slavia. Zdenek Gargulak, from Prague, serves as Head of the Operations
Research Department of the Iron and Steel Research Institute. Meenakshi
S. Krishnamoorthy has been on the faculty of the Indian Institute of
Management, Calcutta, since 1962 and currently holds an appointment
there as Professor in the fields of Operations Research and Management
Information and Control. Stevan Kukoleca is Chief of Chair for Eco-
nomics and Management at the University of Belgrade. Douglas Wood, whose research interest has been in the field of farm economics, is Economics Lecturer at the University of Manchester.

STAFF PROMOTIONS AND CHANGES

I am pleased to announce the promotion of Donald C. Carroll to Professor and the promotion of David P. Taylor and Leon S. White to the rank of Associate Professor. Tenure was granted to Associate Professor Gordon M. Kaufman during the past year. Promoted to Assistant Professor were Milton L. Lavin, Leon H. Liebman, Kenan E. Sahin and Carl V. Swanson.

We are especially pleased to report that Professor Kindleberger has accepted a joint appointment with the Sloan School of Management while retaining his present association with the School of Humanities and Social Science in the Department of Economics.

Professor Douglass V. Brown was on sabbatical leave for the second term; during that period he concentrated his efforts on two substantive areas of research: the prerequisites for the viability of the American labor movement and legalism in labor-management relations in the United States. Professor Billy E. Goetz, on sabbatical leave for the fall term, revised his Management Planning and Control to include in it relationships with operations research and computerized information systems. Professor David Durand visited the Technical University of Berlin for the second term under the faculty exchange program sponsored by the Ford Foundation. Professor Daniel Holland received a Ford Foundation study award to support his studies at the London School of Economics for the spring term. Also on sabbatical leave for the spring term was Professor Edwin Kuh. Professor Franco Modigliani spent the fall term at the Banca d'Italia on an economic research project.

Professor Charles Myers' leave of absence from the Sloan School and the Department of Economics was used to prepare the sixth edition of Personnel Administration (of which he is co-author) for publication in early 1969 and to explore the research area of the impact of computers on the knowledge industry. Professor Arnold Amstutz's leave of absence was supported by a Ford Faculty Fellowship, enabling him to continue his research on the testing and validation of a microanalytic simulation of market interactions.

Former Mayor of Boston John F. Collins joined the Faculty of M.I.T. in January, 1968, as Visiting Professor of Urban Affairs. His appointment spans the Departments of Political Science and Civil Engineering as well as the Sloan School of Management. With us for the fall term
also as Visiting Professors were Richard S. Bower, on leave from the Amos Tuck School at Dartmouth, and David McClelland, on leave from Harvard University.

Karl Scheidl, Professor of Managerial Economics and Banking at the Technical University of Berlin, joined us for the spring term under the faculty exchange program between M.I.T. and T.U.B. sponsored by the Ford Foundation. We are very pleased to note the addition to the School of Associate Professor Lester C. Thurow, who joins us from Harvard University. Professor Thurow will have a joint appointment with the Sloan School and the Department of Economics of the School of Humanities and Social Science.

Also joining us this fall will be Associate Professor Alvin J. Silk, who comes to us from the University of Chicago. Professor Silk will be associated with the marketing area. Additions to our Assistant Professor rank this year include William A. Martin, who joins our operations management group and comes from the Department of Electrical Engineering at M.I.T.; Daniel Quinn Mills, coming from Harvard University, joins us as Assistant Professor and will be associated with the industrial relations area. Alan L. Patz comes to us from Carnegie Institute of Technology and will be an Assistant Professor of organizational psychology and management. Assistant Professor of finance, Myron S. Scholes, joins our faculty from a teaching position at the University of Chicago.

New Instructors this fall will include Thomas P. Gerrity Jr., Robert S. Green and Dennis L. Meadows. Thomas I. Nelson, appointed mid-term last year as a part-time Instructor, will continue with us this fall.

We are fortunate to have with us several fine men as Visiting Professors for the coming year. David Call will have a joint appointment as a Visiting Professor with the Department of Nutrition and Food Science and the Sloan School. Professor Morris A. Horowitz will be on leave from his post as Professor of Economics and Chairman of the Department at Northeastern University and will lead a seminar in Comparative Industrial Relations and Human Resources Systems in the fall term. Samuel I. Katz will be with us in the spring term to conduct a seminar in international finance.

Professor Paul Roberts will be with us as a Visiting Assistant Professor associated with Professors MacAvoy and Nyhart in the management economics area. Joining us this year as a Senior Lecturer is Gordon F. Bloom, former President, Director, and General Manager of Elm Farms Food Co.

Dr. James B. Hartgering, Medical Director for the City of Cambridge,
joined us mid-term last year as a Senior Lecturer and will continue in that capacity.

As is inevitable, there are always a few resignations to record. I want to thank the following men for their service given us in the past and to wish them all well in their new posts. Donald E. Farrar will be associated in the future with Columbia University’s Graduate School of Business. Professor Barnard E. Smith accepted a post with Dartmouth College, upon completion of his tour of duty with the Indian Institute of Management at Calcutta and William Travis accepted a position with the University of California at La Jolla. David E. Berlew accepted the position of Director of the Behavioral Science Center at Sterling Institute. William Gruber will be an Associate Professor at Northeastern University and John M. Thomas has joined the Graduate School of Business at the University of Buffalo.

STAFF ACTIVITIES AND AWARDS

The professional activities of our staff and the distinctions which they garnered during the past year were, as always, legion in number. In this section I record with pride a partial but representative listing of those activities and awards.

Professor Alexander was on leave to the RAND Corporation during the year, where he worked on a study of the economic and political problems of the Middle East.

Professor Amstutz was recipient of a Ford Foundation Faculty Fellowship for the academic year, and was Consultant to the Special Assistant, Secretary of the Navy.

Richard Beckhard served as Chairman of the Executive Committee and Vice Chairman of the Board of the National Training Laboratories Institute for Applied Behavioral Science. He also served as a member of several committees of the European Institute for Trans-National Studies in Group and Organization Development, conducted a workshop and was involved with planning for the Netherlands Training Institute.

Professor Brower was a Visiting Professor of Political Economy at the Universidad del Valle, Cali, Colombia, from June, 1966, to December, 1967.

Professor Brown was a member of the Executive Board, Industrial Relations Research Association.

Professor John F. Collins was awarded the Dr. Ray John Youth Service Award in recognition of his significant contributions of a permanent nature for the betterment of the youth of Boston, April 24, 1968. He also received American Society of Public Administrators’ “Administrator of

Professor Cootner became an Associate Editor of the *Journal of Finance*.

Professor Forrester was elected a Fellow in the American Academy of Arts and Sciences.

Professor Galbraith was selected Vice Chairman of the College on Organization in the Institute of Management Sciences.

Dean Gil served on the Advisory Council of the International Management Institute (C.E.I.), Geneva, Switzerland; and Advisory Council of the University of the Andes. He was also Chairman, Management Development Committee of the Naval War College, Newport, Rhode Island.

Professor Goetz was Chairman of the Engineering Economy Division of the American Society for Engineering Education. He also served on the national Society for the Advancement of Management Taylor Key Award Committee.

Mr. Goodwin continued as a national governor for the Boston Chapter of the Society for the Advancement of Management and also as a Trustee of the International Work Simplification Institute. He served as director of the Executive Conference on Managing Improvement, conducted annually for industry on Cape Cod.

Professor Gruber was consultant to the Atlantic Institute and was delegate to the meetings to study the question, "Technological Disparities and the Management of Technology in the Atlantic Committee."

Professor Haire served on the Behavioral Science Panel of the Defense Science Board (Department of Defense) and as a member of the Board of Trustees of Foundation for Research in Human Behavior, and on the Advisory Board of American Foundation for Management Research.

Professor Hill was a panel member, University of New Hampshire and Tulane University Education and World Affairs meetings and was consultant to Birla Institute of Technology and Finance and Indian Institute of Technology, Kanpur.

Professor Kaufman served as referee for the *Journal of the American Statistical Association*.

Professor Kuh was elected a Fellow in the American Academy of Arts and Sciences.

Professor Little became an Associate Editor of *Management Science: Applications Series*. He also served on the Operations Research Society of America's Education Committee.

Professor MacAvoy served as a member of Secretary of Transporta-
tion's Board of Economic Advisors and was consultant to the Under-secretary of State for Political Affairs.

Professor Marquis was elected President of the New England Psychological Association. He also served as a member of the Committee on Facilities and Development, American Academy of Arts and Sciences; the U.S. National Commission for UNESCO; and the Committee on International Relations, American Psychological Association.

Professor Modigliani was on leave during the fall term as research consultant to the Bank of Italy and also continued research activity on the M.I.T.-Federal Reserve Bank model of the American economy and the parallel model of the Italian economy. He also continued to act as economic consultant to the Board of Governors of the Federal Reserve System and U.S. Treasury.

Professor Montgomery served as Sub-Editor for Computer Applications, Journal of Marketing Research. He also served as referee for Management Science: Applications Series, Journal of Marketing Research, and Industrial Management Review. He was a judge for the dissertation competition of the American Marketing Association.

Professor Moore continues as Director of Public Relations for the American Institute of Industrial Engineers, as Chairman of the Research and Education Committee of the Standards Engineers Society, as a member of the Board of Directors of the Society for the Advancement of Management, and trustee and vice president for research of the International Work Simplification Institute. He also serves on the editorial boards of the Standards Engineering Magazine and the Journal of Creative Behavior.

Richard S. Morse served on the Technical Advisory Board, U.S. Department of Commerce and as Special Advisor to Secretary of Commerce Board of Visitors, Air Force Systems Command.

Professor Charles A. Myers was a member of National Manpower Policy Task Force; Consultant, Assistant Secretary of Labor and Secretary of Labor; and was on the Committee on Education and Human Resource Development, Education and World Affairs, New York.


Professor Nyhart continued to serve as a consultant on development banking to the Organization for Economic Cooperation and Development's (O.E.C.D.) Development Center and also served as M.I.T. Coordinator and Chief Investigator of the M.I.T./B.N.D.E. Development
Bank Training and Research Project, in addition to being consultant to B.N.D.E., our Brazilian collaborator. Professor Nyhart was also President of the Boston Chapter of the Society for International Development.

Professor Pierce served as a member of the Operations Research Committee of the Technical Association of the Pulp and Paper Association.

Professor Roberts was a member of The Institute for Management Sciences (T.I.M.S.) National Council and of the Department of Commerce Technical Advisory Board and was appointed also to its Venture Capital Board and received full membership on the senior board of the Panel on Psychology and Social Science of the Air Force Scientific Advisory Board.

Dr. Robinson was a member of the Education Committee, New England World Trade Center and served as Chairman of the Planning Committee of the Association for Education in International Business. He is Trustee of the Institute of Current World Affairs and Chairman of the Finance Committee. He continues to serve on the Editorial Review Board of the *Academy of Management Journal*.

Professor Schein was appointed to the Board of North Atlantic Research Group, Editorial Board of *Careers Today*, to the Committee on Basic Research in Education of the National Research Council of the National Academy of Sciences and received the Gordon Hardwick Award for Best Paper selected by Middle Atlantic Placement Association.

Professor Shapiro served as a referee for papers submitted to *Management Science* and the *Journal of the Operations Research Society of America*.

Professor Siegel was appointed Director of Graduate Programs, Sloan School of Management, and in December, 1967, Associate Dean, Sloan School of Management. He also continued to serve on the Labor Panel and the Education Panel of the American Arbitration Association.

Professor White was recipient of the first annual Salgo-Noren Award for Excellence in Teaching. He was also Chairman of the Boston Chapter of T.I.M.S., member of the Education Committee of the Operations Research Society of America and Chairman of the M.I.T. Chapter of the American Association of University Professors.

Professor Carroll L. Wilson was Director and member of the Membership Committee of the Council on Foreign Relations and member of the World Peace Foundation. He also served as Chairman of the O.E.C.D. Committee on Research Cooperation, the Advisory Committee to the Economic and Social Council on the Application of Science and Technology to Development, the Science Organization Development Board of
the National Academy of Sciences, and the International Marine Science Affairs Panel of the National Academy Committee on Oceanography. He also is a member of the Advisory Committee to the Economic and Social Council of the United Nations.

Professor Zannetos continued to serve as Vice President and Director of Research of the College of Measurements in Management of T.I.M.S.

STUDENT ACTIVITIES AND AWARDS

The Graduate Management Society is our graduate students' organization. During this year the society increased the effectiveness of its publication, Output. The paper has been published more frequently and expanded its space and hence its content. The society also sponsored a broad range of social activities and invited a variety of speakers to meet with our graduate students. The president of the Graduate Management Society, elected for the fall term, was Thomas F. Riesing and for the spring term, Erik G. Rule.

The Industrial Management Review is now in its ninth year of publication and the editors this past year have done a fine job in improving the Review and expanding its scope and content. Three, rather than two issues will be published yearly in a new format. To meet the problems of an expanding readership, I.M.R. has computerized its subscription and billing procedures. The student editorial board has been expanded from a board of three to one of five or six men. Editorship of the Industrial Management Review is awarded to outstanding graduate students in the Sloan School. For Volume 9, the student editors were: William H. Byrn Jr., R. Douglas Hulse, Henry C. Lucas Jr., William E. Wade Jr., and Walter F. Zwick. For Volume 10, the I.M.R. editors are: Peter R. Brody, David L. Diamond, Lawrence W. Garrett, Robert L. Gipson, James M. Piepmeier, and Anthony C. Taylor.

A third activity organized by Sloan School students involves an investment club, the Sloan Traders. The club was formed by Sloan School students last year to provide real-world experience in portfolio management. The club manages two funds, a Capital Growth Fund begun with a $5,000 investment fund from M.I.T., and the Sloan Traders Investment Appreciation Fund, capitalized by the club members. The club also sponsors speakers of note in the financial community.

I am pleased to note the following awards and honors achieved by students of the Class of 1968. The Brooks Prize in management for the best thesis submitted for the degree of Master of Science in Management was awarded to William E. Wade Jr. Edward A. Seykota received the Sloan School of Management Senior Award for an outstanding senior in
the field of management with high scholastic standing, leadership, and professional promise. For the past two years the Sloan School has been participating successfully in the nationwide competition for the State Farm Companies Foundation Exceptional Student Fellowship Awards for undergraduates majoring in management and economics. In 1967 two of our seniors, Kevin J. Kinsella and Ben G. Garmon, were among the ten winners, and another student, Robert M. Metcalfe, is among the 1968 winners.

GRADUATE ALUMNI ASSOCIATION

The Graduate Alumni Association has moved towards building a national association — having operated successfully on a local and regional basis. The association now has a slate of officers for its country-wide operations, as well as officers representing the New England region.

A New York chapter has been formed and held a well-attended meeting in February, 1968; William May, Chairman of the Board, American Can Company, was the evening speaker. The meeting also served to develop data about the career experiences of the alumni belonging to the New York chapter.

A second issue of the Graduate Alumni Bulletin will be published shortly and an up-to-date directory of the alumni is being compiled. The directory will provide information regarding organizational affiliations and job titles — information that will assist the School in appraising the career patterns of its graduates more precisely and to establish closer contacts with its alumni.

The alumni of the Sloan Fellows Program continue to meet for a work session in New York City and Washington on the occasion of the current Sloan Fellows' study visit to those cities in December and May, respectively.

ADMINISTRATION OF THE SCHOOL

Planning the School's directions for growth and developing the resources required for that growth continue as the principal administrative tasks for this office. I continue to draw essential guidance from the work and wisdom of our School Policy Committee, Personnel Committee, and a newly constituted Resource Development Committee.

Serving on one or more of these committees last year were Professors Brown, Carroll, Cootner, Durand, Forrester, Haire, Hill, Holland, Little, Modigliani, Siegel, Travis, Wilson, and Zannetos and Dr. Gil and Dr. Morse. These men, representing the School's major teaching programs, research areas, and discipline and functional fields, contributed vitally to
strengthening the linkages among our several programs and levels of activity and to keeping open the information lines in our School.

In addition, I have asked Professors Siegel, Charles A. Myers, and Wilson to serve as our School "interpreters" respectively for the School's educational programs, research programs, and outside professional activities. In these "linking pin" roles, these men can help articulate and evaluate for ourselves and for outsiders what we do in each of these sectors of our total efforts.

It has also become clear that the School could profit from a more coordinated review of the many non-curricular and extracurricular functions in which we engage. Toward this end I have appointed a new Committee on Student Career Development and Environment under the chairmanship of Professor Taylor to appraise our plans and make recommendations for change with respect to our activities in student recruitment, selection, orientation, in our concerns with student environment and student activities, of our placement activities and post-placement alumni relations. Possibilities for improvements inherent in the simple recognition of vertical integration in this strand of related activities seem to be numerous and I hope to be able to report on some of them next year.

It has also become evident that the School would profit from greater student participation and membership in a number of our committees and I have proposed the addition of several students to both this last mentioned committee and to the Undergraduate, Master's, and Doctoral Program Committees.

In addition to changes in the membership and design of the School's various committees, there have also been changes during the past year in the School's administrative organization. In the late summer of 1967, John M. Wynne, who was serving the School as Associate Dean, became M.I.T.'s Vice President, Organization Systems, a position in which he will have responsibility to insure that M.I.T. takes full advantage of its organizational and technological resources and opportunities. Mr. Wynne's new position is an important one for all of us at M.I.T., and based on his effective contributions to the development of the Sloan School, I have no doubt about his ability to carry out his new and larger responsibilities. All of us in the School look forward to continuing to work with him.

In August, 1967, Professor Siegel became Director of Graduate Programs in the Sloan School and took on broad responsibility for all aspects of these programs. In December, 1967, he accepted the position of Associate Dean. Throughout this period Dean Siegel, who continues to hold his joint appointment as a Professor of Industrial Relations in the Sloan
School and in the Department of Economics and who has continued to teach part-time in several programs in the School, has contributed enormously to all aspects of administration in the School. As always, Peter Gil's very effective work with all of the Executive Development Programs that the School offers has continued to keep the quality of these programs among the highest to be found anywhere. Miss Priscilla A. Karb, as Associate Director for Executive Programs, has helped Dr. Gil in the administration of these programs and has contributed substantially to their smooth administration. Miss Miriam Sherburne, Assistant for Graduate Programs, and Miss Esther Merrill, Assistant for Undergraduate Programs, have had to cope this year with a greater degree of program change than is typical and have as always proven their distinction in handling these difficult jobs. Miss Gertrude E. Burns, as Administrative Officer for the School, has built upon an already long record of distinguished service in her effective management of the School's financial office this year. As a research associate, J. David Raney continued to work with me and with Dean Siegel on some quantitative analyses of the School's own operation, begun last year, and on other projects related to planning and administration of the School. Finally, all the supporting administrative and secretarial staff of the School enabled all of us to carry out our plans and deserve our earnest thanks.

SUMMARY AND PROSPECTUS

This year we have continued to review and to some extent revise our programs, our posture vis à vis the outside world, and our internal organizational design to help implement our plans.

We have asked and continue to ask: How do we continue to improve the already distinguished work and impact of the School? How do we organize to do it? How do we assure the inflow of the crucial human and financial resources we deem essential for carrying through these plans?

We have devoted significant efforts this year to the discussion of possibilities and priorities in our list of "things it would be nice to do and why we can't do them all." The important criteria for choice are several; the weights to be attached to each factor affecting such decisions are variable; the ultimate choices themselves are complex and vital. No one familiar with the lively discussions in recent years of the uses and abuses of the university and its parts can fail to be aware of perplexities in the definition and clarification of our School's role and stance.

I believe that we have in our deliberations and our choices safeguarded against the extremes of the monastic institution on the one hand and of the "public utility" on the other. In our ongoing choice to pursue and en-
encourage the development (and whenever possible, the effective integration) of basic analytical disciplines, functions, concepts and tools, we have assured our faculty and students that scholarship and research are the vital base for all we do. In our more recent choice to seek to apply these analytical concepts across many fields of potential application (the management of education, health services, the public sector, as well as industry), we have opted for what is in the best interests of both scholarship and service. The analytical synergies emerging in management demand the expansion of fields for research and of the contextual boundaries for its applications. The latter choices in turn have permitted us to focus with greater clarity on the relevance of our School's efforts to the key issues in the management of complex organizations a generation from now, as well as for today's problems. The gulf between the two is not always wide, but the boundaries of today's and tomorrow's issues are not wholly coterminous either. How successful we have been and can be in sustaining the right balances in these choices we can know fully only a decade or two hence.

In the interval, the choices shall remain difficult and the problems compelling. The enormous talents of the School's faculty and students and the strong support of our activities by a helpful and understanding M.I.T. administration lead me to hope we can continue to make choices appropriate to our obligations and opportunities.

WILLIAM F. POUNDS
As I look back over my first full year as Dean of the School of Science, I am very much aware of the high level of activity and of the relatively rapid changes in instructional and research programs. It is perhaps surprising that science continues to change in such basic ways, but our ways of looking at the nature of matter, the earth, and at the physical basis of life are undergoing major changes. These changes are felt first in research, where they originate, but they quickly have an impact on the instructional program at M.I.T.

A number of changes were made in the core subjects in chemistry, mathematics, and physics, which are taken by all students at the Institute. New subject matter and new text materials were introduced in Chemistry 5.01, which was taught by Professors Richard C. Lord, Dietmar Seyfferth, and John S. Waugh in the fall and by Professors Charles D. Coryell and James L. Kinsey in the spring. A group of applied mathematicians took the basic responsibility for the required mathematics subjects. In the fall 18.01 was taught by Professors William G. Strang and Alar Toomre; 18.02 was taught by Professor Harvey P. Greenspan; and 18.01S (a more abstract presentation of calculus) was taught by Professor Sigurdur Helgason. In the spring 18.02 was taught by Professors Manuel Blum and Toomre. Professor Gian-Carlo Rota of the Department of Mathematics accepted responsibility for the Freshman Advisory Council and therefore will be very much concerned with the core subjects. In the fall Professor Harald A. Enge taught Physics 8.01 and Professor Anthony P. French taught 8.02. In the spring Dr. Harry M. Schey taught 8.01 and Professors French, Albert G. Hill, and Philip Morrison taught 8.02. Professor French also served as Chairman of a
subcommittee of the Committee on Academic Policy concerned with core requirements.

There will be a number of changes in the core subjects next year. The Department of Physics will offer two new varieties of 8.01, so that students may select between the three possibilities. The Department of Chemistry has received approval of their recommendation that the chemistry core requirement may be satisfied by Chemical Thermodynamics, 5.60, or Organic Chemistry, 5.41, as well as by Chemistry 5.01.

About one-third of the students at the Institute are majoring in one of the seven departments of the School of Science; 34 per cent of the undergraduates who have declared a major and 29 per cent of the graduate students are in the School of Science. However, because of the large instructional responsibilities of the Departments of Physics, Mathematics, and Chemistry, the School of Science teaches more than a third of the units each term; in the fall of 1967-1968, 39 per cent of the instructional units were taught in the School of Science.

The number of graduate students in the School increased 3.0 per cent (from 1,084 to 1,117) from the fall of 1966 to the fall of 1967. The largest increases were in the Departments of Chemistry and Physics. The number of undergraduate majors decreased 6.4 per cent (from 992 in 1966 to 929 in 1967).

Postdoctoral appointments represent an educational activity that we tend to forget. A survey taken by the National Science Foundation in the fall showed that we had the following numbers of postdoctoral appointments: Biology, 81; Chemistry, 73; Geology and Geophysics, 13; Mathematics, 7; Meteorology, 10; Nutrition and Food Science, 10; and Physics, 47. These people add considerably to research programs and some of them served as part-time instructors.

The provision of adequate space and facilities is always a problem of major concern to a dean, and I am happy to report on the progress of projects started by Dean Jerome B. Wiesner. The remodeling of space on the third and fourth floors of Building 6 for the Center for Theoretical Physics was completed, and the occupants are very pleased with the design and execution of the plan to make this area as attractive as space in a new building. The Center was dedicated during the week of March 18th concurrently with the Center for Advanced Visual Studies. The dedication program brought together artists and scientists from many places to discuss the relationship between art and science. The talks, discussions, and visits to the new facilities were attended by more than four hundred people.

The Camille Dreyfus Building for the Department of Chemistry is
showing good progress and should be available for occupancy in the fall of 1969. This will provide much-needed space for the Department of Chemistry and will open a physical link between Chemistry and Biology. When Chemistry moves, it will be possible to provide about 10,000 square feet for the Department of Mathematics.

The 400-Mev electron accelerator (LINAC) is now under construction at Middleton under the responsibility of Professor Peter T. Demos of the Laboratory for Nuclear Science. This facility will make it possible for our physicists to enter interesting and challenging new areas of research on nuclear structure using electrons as probes.

During the year the Department of Mathematics moved into about 5,000 square feet of new space in Building 24, and the Department of Physics moved into about 5,000 square feet of new space in the same building.

There has been a good deal of apprehension during the year about Federal funds, and a few projects have suffered, but the most serious effect probably has been in the slowing down of planning and aspirations to develop new research activities. The Sloan Research Fund has been of assistance on a number of occasions in making it possible for us to move ahead. The National Institutes of Health Institutional Grant has also helped in this way in the biological sciences. However, there are large projects which we would like to see develop that will definitely require outside resources. Examples are the 440-foot radiotelescope being proposed to the National Science Foundation by NEROC (Northeast Radio Observatory Corporation), as described in Provost Wiesner's report, and HYLAB (Heavy Ion Laboratory at Burlington), under the auspices of the Laboratory for Nuclear Science, which has been proposed to the Atomic Energy Commission. The Sloan Foundation made a very welcome grant to the Department of Nutrition and Food Science for research on single-cell protein for nutritional use.

During the year the biological sciences have received a good deal of attention because M.I.T. continues to seek ways of making even greater contributions to the life and health sciences. The process of self study and planning, begun last summer with the Summer Study on Life and Health Sciences, has been continued with joint meetings of representatives of the Harvard Medical School and M.I.T. on education, research, and health services. Subcommittees have been active during the year.

The joint graduate program in oceanography with the Woods Hole Oceanographic Institution, which had been under development for several years, was formally inaugurated on May 8th in a dockside ceremony in which Dr. Paul Fye signed for the Woods Hole Oceanographic
Institution and President Howard W. Johnson signed for M.I.T. Under the joint program some of the subjects will be taught by M.I.T. staff and some will be taught by the Woods Hole staff. A new joint subject is being given this summer. Some 40 students will be enrolled in the program in September, 1968, some of them coming from the Department of Geology and Geophysics and some of them coming from the Department of Meteorology. By working together, the two institutions can provide a stronger program of education and research than by working separately.

Another field in which various types of cooperative arrangements have been developed is the area of optical astronomy. Research in radio-astronomy carried out by the staff of the Lincoln Laboratory and the Departments of Physics, Geology and Geophysics, and Electrical Engineering has led to an increasing interest in optical astronomy. The research on X-ray astronomy carried out by the Department of Physics, the Center for Space Research, and the Research Laboratory of Electronics has also increased interest in this field. Instructional and undergraduate research programs in optical astronomy have profited from the new exchange program with Wellesley College, since they have a new 24-inch reflecting telescope.

Professor William T. Martin completed his responsibilities as Head of the Department of Mathematics after 21 years. He has presided over a period of major change and strengthening of the Department. In his first annual report in 1947-1948 Professor Martin reported that there were 54 Course XVIII undergraduate students (compared with 299 in 1967-1968) and 53 graduate students (compared with 145 in 1967-1968). During this 21-year period Professor Martin was away twice: he spent academic year 1951-1952 at the Institute for Advanced Study in Princeton, and he spent the spring term of 1964 at the University of Pisa. In commenting on Professor Martin's services as Head of the Department of Mathematics, I can think of no more fitting words than the ones he wrote 20 years ago, in his first annual report, about Professor Henry B. Phillips, who was in charge of the Department from 1934 until his retirement in 1947:

It is not possible to enumerate all of the many contributions which he made to the Department and to the Institute but two of the most significant ones are his strengthening of the undergraduate and graduate offerings of the Department, and his influence and leadership in the development of a Department in which good teaching and fundamental research were both stressed. For these and many other contributions the Department is deeply indebted to him.

Professor Norman Levinson will become Head of the Department in
September, and he will be assisted in the administration of the Department by Professor Harvey P. Greenspan, Chairman of the Committee on Applied Mathematics, and by Professor Kenneth M. Hoffman, Chairman of the Committee on Pure Mathematics.

During the year several new appointments of tenure faculty have been made from outside the Institute. Professors John W. Milnor and Elliot H. Lieb have joined the Department of Mathematics and Professors Bruno Coppi and Sergio P. Fubini have joined the Department of Physics.

Members of the School of Science received so many honors during the year that it is not possible to list them here, but I am happy to report that Professor Isadore M. Singer of the Department of Mathematics became a member of the National Academy of Science.

ROBERT A. ALBERTY

DEPARTMENT OF BIOLOGY

The number of students registered in Course VII has continued to increase. During the past year we have had 139 undergraduate students concentrating in the life sciences. It is significant that the total number of undergraduates at M.I.T. has remained constant. The increase shows that a larger proportion of students admitted to M.I.T. continues to be attracted to biology.

CURRICULUM

An expansion in Biology 7.02, General Biology Laboratory, was made possible by adding a new project of experiments with animal cells planned and taught by Professor David Baltimore, who joined the Department during the year. We were able to accommodate 102 students rather than 69 as in the previous year. This made it possible for many students in fields other than life sciences to choose 7.02 to fulfill their laboratory requirement. In the Genetics and Microbiology Laboratory, 7.031, a new approach was tried for one-half of the class. The students had as their task the isolation of mutants of the bacterium Escherichia coli and their complete genetic and biochemical identification. This experience proved to be of great educational value by offering the student the challenge of solving problems by consulting the scientific literature and using his own judgment in following procedure.

New graduate subjects offered for the first time were 7.24, Topics in Bacteriology, a seminar taught by Professors Maurice S. Fox, Boris Magasanik, and Saul A. Yankofsky, and 7.25, Topics in Virology, a
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seminar taught by Professors Salvador E. Luria, Sheldon Penman, and Ethan R. Signer.

RESEARCH

During the last ten years the Department has developed considerable strength in the area of molecular biology, a field of study and research based on biochemistry and genetics. The great advances made in molecular biology, frequently by the use of micro-organisms as experimental material, have provided a solid foundation for the attack on problems specific for higher organisms, such as development and the immune response. A number of the members of our Department are now investigating these problems.

The scope of the research activities of the Department has increased significantly through the interests of our new members. Professor Paul R. Schimmel whose appointment is joint with the Department of Chemistry, is a biophysical chemist studying the mechanisms of enzymatic reactions by the temperature jump and similar techniques. Professor Corrado Baglioni is working on the synthesis of antibodies, and Professor Lisa A. Steiner on the structure of antibodies. Professor Baltimore is studying the formation of animal viruses in cell culture.

An annual publication entitled Research Summaries, summarizing research work done in the Department of Biology, is available at Department headquarters.

PERSONNEL

New appointments to the Department of Biology include Dr. Harvey F. Lodish and Dr. Thomas M. Jovin as Assistant Professors and Dr. U. L. RajBhandary as Associate Professor. Dr. Lodish received his Ph.D. from Rockefeller University in 1966 and is presently a Postdoctoral Fellow at the Medical Research Council Laboratory of Biology, Cambridge, England. Dr. Jovin received his M.D. from Johns Hopkins Medical School in 1965 and is presently a Research Associate at the Max Planck Institut fur Physikalische Chemie, Germany. Dr. RajBhandary received his Ph.D. from the University of Durham, England, in 1961, and is presently holding the position of Assistant Professor at the University of Wisconsin.

Professors Joel E. Brown, Charles E. Holt III, and Signer have been promoted to the rank of Associate Professor.

Professor Vernon M. Ingram has been awarded the Allan Award of the American Society of Human Genetics.

Professors Robert M. Dowben, Cyrus Levinthal, Bruce H. Pomeranz and Yankofsky are leaving our Department to accept other academic
positions. Professor Dowben has accepted a position at Brown University. Professor Levinthal will hold a position at Columbia University. Professor Pomeranz is returning to Canada and has accepted a position at the University of Toronto. Professor Yankofsky is returning to Israel and will be holding a position at the University of Tel Aviv.

During the coming year Professor Fox has been granted sabbatical leave to carry on research at the Laboratorio Internazionale di Genetica e Biofisica, Naples.

Professor Ingram was on leave of absence this year, and was in residence at University College, London, England.

Professor Alexander Rich was on leave for the spring term and was in residence at the Weizmann Institute, Israel.

BORIS MAGASANIK

DEPARTMENT OF CHEMISTRY

Thirty-four undergraduates were awarded the Bachelor of Science degree in chemistry this year. Of these, 24 were admitted to various graduate schools throughout the country as candidates for the degree of Doctor of Philosophy. Ten graduates took positions in industry. Thirty-nine doctoral candidates were awarded the Doctor of Philosophy degree during 1967-68. From among that number, eight accepted academic positions, 15 accepted temporary postdoctoral appointments, and 16 accepted industrial positions.

During the year there were in residence 283 graduate students devoting full time to study and research in preparation for the doctoral degree. Of these, 112 held predoctoral fellowships, 76 were teaching assistants, and 83 were research assistants. There were in residence last year 75 postdoctoral fellows and research associates devoting their full time to study and research in collaboration with the members of the staff. Among these postdoctoral research associates were 36 foreign nationals visiting here from England, Australia, Israel, Canada, France, Germany, Ireland, Italy, Switzerland, and Yugoslavia, among other countries. Nine of the 11 postdoctoral fellows were awarded NSF (National Science Foundation) or NIH (National Institutes of Health) postdoctoral fellowships.

PERSONNEL

Dr. John S. Lewis has accepted a joint appointment in the Departments of Chemistry and Geology and Geophysics as Assistant Professor. Dr. Lewis received his Ph.D. degree at the University of California, San
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Diego, in La Jolla. This is the first joint appointment between the two departments, and we look forward to active cooperation in fields of mutual interest.

Professor Dietmar Seyferth was on sabbatical leave during the spring term at the University of Munich in West Germany.

Professor Glenn A. Berchtold was on sabbatical leave for the academic year at the Eidgenossische Technische Hochschule in Zürich, Switzerland.

Professor Walter R. Thorson has resigned from the Institute and has accepted an appointment as Professor of Chemistry at the University of Alberta in Edmonton, Canada, as of June 30, 1968. He joined the staff as an Assistant Professor in July, 1958, and was appointed Associate Professor in 1963.

Professor David K. Roe resigned from the Institute and has accepted an appointment on the faculty of the Oregon Graduate Center, Portland, Oregon. He came to the Institute in July of 1962.

During the past academic year the Department was privileged to have three Arthur D. Little Visiting Professors. Professor Ignacio Tinoco Jr. from the University of California, Berkeley, presented three lectures on "Structures and Optical Properties of Nucleic Acids." Professor G. Wilse Robinson of the California Institute of Technology presented three lectures on electronic structure of solids and the dynamics of the liquid state. Professor R. Stephen Berry of the University of Chicago presented three lectures on ionization and excitation processes.

Professors Daniel S. Kemp and Robert J. Silbey have been awarded Alfred P. Sloan Fellowships.

CURRICULUM

During the year the beginning chemistry subject 5.01 was given for the first time as a one-term subject without laboratory. It was decided to focus attention on the basic structural and mechanistic concepts of chemistry in atomic and molecular terms, an approach that is sometimes called quantum chemistry. The subject began with a study of the electronic structures of the atoms and their relation to the Periodic Table of the elements. The concepts of atomic energy levels and quantum numbers were developed by treatment of the spectral series of the hydrogen atom. The wave nature of the electron, atomic orbitals and electron spin were introduced and applied to the understanding of the spectra and structures of sodium and helium. The Pauli principle and the relations between atomic energy states and quantum numbers were then used to develop the structure of the Periodic Table. Chemical binding was next intro-
duced in terms of molecular orbitals built up from atomic orbitals. Chemical bond strengths and molecular geometry were treated and illustrated with the structures and properties of small molecules. Quantization of molecular energies of vibration and rotation and their measurement by molecular spectroscopy were discussed briefly.

Next the kinetic theory of gases was introduced as a basis for the behavior of real gases as a function of temperature and pressure. The ideas of mean free path, collision diameter, mean molecular velocity, and velocity distribution were set forth and examined quantitatively. These concepts then served as the basis for treatment of chemical reactions in gaseous systems. The rate, order, and mechanism of chemical reactions were defined and illustrated. The properties of reactions of different order, such as the dependence of reaction half-life on initial concentration, were treated in some detail, as was the dependence of reaction rate on temperature. The subject concluded with a consideration of the mechanisms of chemical reactions in solutions.

The response of a considerable fraction of the class to this rather rigorous physical treatment of introductory chemistry was quite favorable. It is planned to continue along similar lines during the coming academic year, making those changes in the details of the treatment that were suggested by experience.

It was possible to conduct 5.01 recitation sections with much reduced enrollment: about 12 students per section. Teaching assistants in each section had considerable freedom in choosing additional topics to be discussed, in setting examinations, and in distribution of grades.

A project laboratory entitled "Laboratory Problems in Chemistry" was introduced for the first time this year. In this subject, students selected a small number of experimental topics for individual study, designed and assembled the appropriate apparatus, carried out the measurements, and interpreted whatever results they had been able to obtain. The projects available ranged from simple spectrophotometric and chromatographic studies to complex systems such as a mass spectrometer, nuclear magnetic resonance, or spectroscopy at liquid helium temperatures. Five faculty members were involved in developing projects and guiding students in this laboratory; the National Science Foundation provided some of the new equipment required. Twenty-seven students elected the subject during its trial run in the fall term, and 48 signed up in the spring term. Both the students and the instructing staff enjoyed the informal, exploratory atmosphere prevailing in the laboratory. The subject is expected to continue into the new curriculum with about 50 to 70 students per term; when coupled with such subjects as the 8.14 physics
project laboratory, and others which may be initiated in other departments, it should be possible to offer every student an extensive laboratory experience during his first year.

A complete revision of the undergraduate curriculum in laboratory instruction will become effective for the sophomore class as of the fall of 1968. Rather than follow conventional lines of the traditional fields of inorganic, organic, physical, and analytical chemistry, the new laboratory curriculum will attempt effective integration of methods and techniques as used in modern chemical work and research. Professors Herbert O. House, Richard H. Holm, David N. Hume, and David P. Shoemaker have devoted the spring term to developing the integrated undergraduate laboratory and will continue to do so during the summer.

FACILITIES

The construction of the Camille Dreyfus Chemistry Laboratory is now progressing at the anticipated rate. Excavation problems slowed the initial phases of the work so that occupancy is expected by late, rather than early summer of 1969. By the time the new building is occupied, remodeling of the space retained by the Department in Buildings 2, 4, and 6 should be well under way. Plans for the remodeling are being detailed now and work will be started as soon as these are completed. The logistics of moving the various research groups and teaching laboratories require spreading the remodeling work over approximately a three-year period. The final result will be that the entire Department will have first-class office and laboratory facilities and that modern laboratory space will be available for the new undergraduate integrated laboratory program.

The Department purchased three major pieces of equipment: an RMU-6E (Hitachi) mass spectrometer and two T-60 (Varian) nuclear magnetic resonance spectrometers. This new equipment, as well as a large amount of other departmental service equipment, has been combined into a departmental service facility under the direction of Dr. John S. Fleming.

RESEARCH

The faculty of the Department is active in research in all areas of chemistry. There follows a description of a few research programs which are representative and indicative of the wide range of interests.

Professor Kerry W. Bowers and his students have, by successfully combining high-intensity flash discharges with a specially designed rapid scanning electron spin resonance spectrometer, extended the sensitivity
of ESR for the study of transient photo-produced paramagnetic species by many orders of magnitude. By this technique the first N - π* triplet states have been observed and information regarding their structure has been extracted. Also the first studies of the geometrical conformations of the lowest excited triplet state have been successfully carried out for large molecules.

The research program of Professor David M. Chipman, concerned with the general problem of the chemical mechanisms of enzymic reactions, has taken two main directions. The first is the study of some organic reactions as models for biological reactions, in particular oxidation-reduction reactions involving the nicotinamide coenzymes NAD and NADP. He is examining the effects of several parameters, including charge-transfer interactions, on the kinetics and equilibria of pyridinium-dihydropyridine interconversions, in an attempt to define the mechanisms of such processes further. He also hopes to test several hypothetical mechanisms for the enzymic catalysis of nicotinamide coenzyme reactions by means of such model studies.

The second major aspect of his research is a study of the details of the enzyme-substrate complex formation process, particularly for enzymes which form rather specific complexes with oligomeric or polymeric substrates. It appears that complex formation in such cases may not only determine substrate specificity, but may also significantly affect the rate of the chemical reaction step. His approach is to study the effect of systematic changes in substrate structure on enzyme-substrate complex formation equilibria and dynamics. He has recently applied this technique to the enzyme lysozyme.

Several aspects of transition metal organometallic chemistry and transition metal coordination chemistry have been studied by Professor Alan Davison.

Considerable progress has been made in understanding the details of the rapid intramolecular rearrangement reactions which occur in metal organic molecules such as π-C₅H₅Mo(CO)₅π-C₅H₅, C₅H₅Ru(CO)₃ and (CH₃)₃SiCH₃C₅H₅. The organic fragments have more than one possible mode of attachment to the metal and a rapid site exchange process between the various possibilities can quite often be studied by temperature dependence of their NMR spectra.

Symmetrically disubstituted 1,1'-ferrocene derivatives in which the substituents can function as donor groups towards metals have been explored, and a whole new class of bidentate chelate ligands has been discovered; the chemistry of transition metal complexes with these ligands is being actively explored.
Continuation of work on complexes related by facile one-electron transfer reactions has been possible with the synthesis of bisperfluoro-methyl-1,2-diselenetene which is used as a precursor for 1,2-diselenato complexes.

Professor Holm's research is broadly concerned with the synthetic, structural, and electronic properties of transition metal complexes. The relative stabilities in solution of the planar and tetrahedral stereoisomers of four-coordinate complexes are being investigated as a function of coordinated metal ion and nature of the donor atom set, with particular emphasis placed on the stereochemical effect of replacing oxygen with sulfur. A synthesis of dithiotropolonato metal complexes has recently been accomplished and the systematic coordination chemistry of this ligand system together with the electronic properties of the complexes are under investigation. Metal complexes containing ligands with two, three, and four asymmetric centers have been prepared and an NMR method devised by which all possible isomers can be detected and identified in solution. A direct outgrowth of this work has been the first stereo-specific synthesis of tetrahedral complexes of known absolute configuration. A new class of dithiolene complexes, dimeric species containing cobalt and iron, has been discovered and their chemical and electrochemical properties investigated in detail. Certain of these complexes have antiferromagnetic properties and a theoretical interpretation of their magnetic susceptibilities is being worked out. Nuclear magnetic resonance has been applied to a study of the reaction sequence operative in model systems which non-enzymatically effect transamination of amino acids and α-keto-acids. The reactive intermediates involved have been detected and identified, thereby permitting a more definite specification of the reaction sequence than heretofore.

Among recently fruitful research results by Professor Kemp are developments in the areas of enzyme model studies and in peptide synthesis. A study of the hydrolysis and hydrazinolysis of isotopically labeled O-salicoyl salicylic acid has yielded generalizable conclusions that define stringent conditions which successful forms of several simple enzyme mechanisms must meet. Recent peptide developments include synthesis and study of the 7-hydroxybenzisoxazolium cation, a new and versatile reagent for formation of the peptide bond, and construction and testing of isotopic dilution tests of optical purity which, relative to other assays, provide orders of magnitude greater sensitivity. A combination of these developments permits critical assessment of new, simple approaches to peptide synthesis. Present activity is concentrated on generalizations of these results, as well as on explorations of problems arising from steric
hindrance, and extent of racemization, as well as the problem of side-chain reactivity which arises with amino acids such as arginine, histidine, serine and cysteine.

Professor James L. Kinsey recently completed the study, using crossed molecular beams, of a number of systems in which long-lived complexes are formed in a single binary collision. Although practically all theories of chemical reaction processes invoke such complexes, all the systems previously studied in molecular beams failed to exhibit this behavior. The general importance of such species in reactions is still uncertain, but it now appears likely that they play an important role in many cases. Efforts in this area are now concentrated on the detailed properties of the complexes, particularly the inelastic processes arising in complex formation.

Professor Kinsey has extended some earlier theoretical work on rotationally inelastic collisions in He-H₂ mixtures at low energies to include all the energetically allowed processes for energies below kT for T up to about 600°K. The earlier results, which included only collisions that reorient the molecular angular momentum without altering its magnitude, were compared to NMR relaxation times to obtain information about the anisotropy of the intermolecular potential. The extended results can also be compared to other transport properties to determine the potential more accurately. Work is also in progress on molecular beam scattering experiments on He-H₂ collisions.

Professor Paul R. Schimmel is pursuing two principal types of research investigations: (1) dynamics and thermodynamics of physiologically important reactions; (2) experimental and theoretical studies of biological macromolecules.

Professor Schimmel is investigating the interaction of lysozyme with mono- and oligosaccharides. (Some of these studies are being done in collaboration with Professor Chipman.) The dynamics of these interactions are being investigated by the temperature-jump relaxation method. Relaxation times have been observed in the range of 0.5-10 milliseconds for the interaction of lysozyme with di- and with tri-N-acetyl glucosamine. These relaxation times are due to the bimolecular step. The data obtained are consistent with and readily explained by the three-dimensional structure of crystalline lysozyme and crystalline lysozyme-saccharide complexes. Spectroscopic studies of the lysozyme-alpha-N-acetyl glucosamine complex are almost complete. His data suggest that two ionizable groups on the enzyme’s active site are intimately involved in the binding of this saccharide to lysozyme; he is attempting to identify the chemical nature of these groups and their exact position in the chain sequence. These
dynamical and equilibrium studies, in conjunction with the crystallo-
graphic data, show great promise for providing detailed insight into the
dynamic and static aspects of enzyme specificity, reactivity, and the rela-
tionship between enzyme structure and function.

Professor Schimmel is also initiating investigations of chemical relaxa-
tion in biological model systems, employing the high-frequency ultrasonic relaxation method. The construction of the necessary equipment is almost complete. His interest focuses on phenomena occurring with time constants of 1-100 nanoseconds. Typical topics of interest are the dynamics of base-stacking in oligonucleotides, rotational isomerism in peptides, "hydrophobic bonding" and associated water structure forma-
tion and breakdown, hydrogen bonding.

A major effort is being directed at the physical chemistry of the first two steps of protein biosynthesis, and the related topics of the structure, function, and mechanism of action of a particular amino acid (isoleucine) activating enzyme and its cognate tRNA. Professor Schimmel is currently isolating this enzyme, and its cognate tRNA, from *E. coli*.

Theoretical studies focus on configurational transitions (folding-
unfolding) in proteins, and on calculations of configurationally dependent properties of certain biological polymers.

Professor John S. Waugh's group has been developing a new class of magnetic resonance experiments, one of whose main goals is the exten-
sion of the usefulness of so-called "high-resolution" NMR to the solid state. The chemical shifts and spin-spin interactions, which give the NMR method most of its power in the analysis of molecular structure, have heretofore been measurable only in the liquid state, where the effects of the otherwise dominant dipole-dipole interactions are averaged out by molecular action. In Professor Waugh's experiments the dipole-dipole interactions are effectively removed, even in solids, by a rapid motion of the nuclear spins brought about by a train of intense radiofrequency magnetic field pulses. Early experiments and theoretical analysis support the hope that the method may become generally applicable to a wide variety of substances, and materially extend the power of NMR methods, particularly to the study of substances of high molecular weight.

JOHN ROSS

**DEPARTMENT OF GEOLOGY AND GEOPHYSICS**

The investigations of the Department of Geology and Geophysics in 1967-68 range over the planetary system. We have made special studies
of Mars, Venus and Mercury, but the earth continues to receive a major share of our attention. In this summary, I will review some of the outstanding accomplishments, starting with the planets and ending with the very center of the earth.

Planetary physics is the newest discipline to be added to our curriculum and our research effort. The techniques of this rapidly developing field include radar observations, spectroscopic observations, precision studies of the rotations and the orbits of the planets and of satellites, planetary probes, and the application of theoretical-numerical celestial mechanics of finite deformable bodies. The radar data from Haystack in Arecibo have been used to recalculate the radius of Venus. The latest value of 6,050 kilometers differs significantly from the value of 6,085 kilometers based upon the data of the Soviet and U.S. space probes Venera-IV and Mariner-V. The question is an important one because it affects the composition, density, and temperature of the Venusian atmosphere. The radar data suggest the possibility that Venera-IV underestimated its altitude by 30 kilometers and did not actually land on the surface of Venus as has been proposed by the Soviet experimenters.

A study of the surface of Mars, using radar techniques, shows topographic variation of some 12 kilometers. There is no obvious connection between the height of the surface and the location of bright and dark areas. On a continental scale, the topography of Mars is much smoother than that of the earth.

It has recently been found that Mercury's axial rotation is locked to its orbital motion. The mechanism for this has been studied in some detail. It involves the role of tidal friction in slowing the spin rate to $3/2$ times the orbital mean motion. The effect of perturbations of Mercury's orbit was shown to be important in the capture into a resonance lock.

The earth's magnetic field is variable — on a long-time basis because of fluid motion in the core of the earth, and on a short-time basis because of magnetohydrodynamic effects in the outer magnetosphere several hundred kilometers above the surface. One such disturbance was found to be related to the sudden amplification of pre-existing Alfvén waves propagating in the magnetosphere. These resonances and their damping result from the non-isotropic distribution of particles in this region. It is interesting that fluctuations in the magnetic field originating in the magnetosphere provide a powerful tool for studying the earth's interior. These magnetic variations induce currents in the earth whose magnitude depends upon the distribution of electrical conductivity with depth in the earth. Since conductivity depends primarily on temperature, we have a means of deducing temperatures at depth. Such a study was carried out
in New Mexico and Arizona, and anomalously high conductivities corresponding to temperatures quite close to the melting point in the upper mantle were found. These results are also consistent with the excessive heat flow and seismic anomalies associated with this region.

The crust of the earth provides the foundation for our structures, the natural resources for our industries. It is continually being examined by geologists who wish to know something about its mobility, its age, its strength and fracture properties. Two very ancient blocks of continent have been discovered this past year, one in Venezuela and another in western Liberia. Both are at least three billion years old, and both include similarly ancient ores of economic importance. It is possible that they were once a single province, split apart in the past one hundred million years by continental drift.

We have been studying the properties of rocks which are strained under high confining pressures in the hopes of discovering the earthquake mechanism. This past year we have been producing earthquakes in the laboratory by increasing the fluid pore pressure. In nature such pore pressure fluctuations may occur by the release of fluids from minerals, or artificially by pumping fluids into deep wells.

The sea floor is thought by many to hold the key to the solution of the major problems of geology. Although the joint degree program in oceanography involving M.I.T. and the Woods Hole Oceanographic Institution became final only a few weeks ago, M.I.T. faculty and students have participated in about a half-dozen cruises in the past year. They have been concerned primarily with studying the rocks and sediments on the sea floor by observing the flow of heat from the deep interior, the thickness of sediments, the physical properties of sediments and rocks dredged from the sea floor, and the variations of the earth’s gravity and magnetic field over the oceans. Data have been accumulated from the Red Sea, the Mediterranean Sea, and the Atlantic and Pacific Oceans in the past year.

We have not neglected the ocean in favor of the sea floor. This year, the ocean telescope reached a point that may allow us to install it in the coming summer. This device consists of an array of sensors located off the Bermuda coast and cabled to recorders on land. Its purpose is to record internal waves, large fluctuations within the ocean that are distinct from the swell which rides on the surface. These waves are known to exist within the ocean, but they have rarely been observed, so that their properties are as yet unknown. How they are generated and how they affect ocean weather are among the problems of this research project.

Returning to the rocks of the crust and upper mantle of the earth, we
are concerned with the way they have differentiated in their evolution over geologic time. In the Department during the past year, new laboratory facilities were constructed which can duplicate conditions in the deep interior to depths of a few hundred kilometers and temperatures of 1500°C. In this way we can study the assemblages of minerals that form under various conditions, and we can investigate the physical properties of these materials under conditions similar to their natural occurrence. We expect many interesting results to emerge from these new facilities in the next few years.

Analogous to the ocean telescope is a seismic telescope which we use to explore the earth’s deep interior. This, of course, is the Large Aperture Seismic Array (LASA) consisting of some 500 seismographs located over a 200-kilometer square area in Montana. This facility was installed by Lincoln Laboratory, and we have used it heavily in our own research program. The data from LASA and the recent data of the natural ringing frequencies of the earth have been used to explore the over-all structure of the earth from the surface to the very center. Lateral variations have been found, not only in the shallow layers, but also in the deep interior. The density at the very center of the earth was found to vary between 13.5 and 14.0 g/cm³ corresponding to a mixture of 75 per cent iron and 25 per cent nickel. Rapid density fluctuations were found at 400 and 600 kilometers, probably corresponding to phase transitions in the earth. Very complex structures were found for the outermost 300 kilometers of the earth, signifying lateral compositional variations to a degree not heretofore expected.

We have given much attention to our undergraduate and graduate curricula in the past year. We have reorganized the undergraduate advisor system to make it more responsive to the needs of the students. The program has been made less restrictive, and more options are being offered. We have already noted that the enthusiasm and morale of the students have increased. We have solicited advice from the students in making these changes, and graduate students already have participated as members of several departmental faculty committees.

Course xii-B, an unlabeled S.B. degree, has received final approval from the Faculty and administration. This Course will essentially remove the traditional boundaries between departments and offer a degree in the physical sciences on behalf of the School of Science. It is directed toward those students who wish a broad education in science, but who wish to enter the social sciences or the humanities when they graduate. It is also directed toward those students who wish more time before specifying a major field or who wish to enter interdisciplinary fields like the environ-
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mental sciences or applied science. This is an experimental program, and we plan to restrict the enrollment in the early years while we gain experience and evaluate different procedures.

FRANK PRESS

DEPARTMENT OF MATHEMATICS

The Department continues to have a large number of majors, both undergraduate and graduate, and the over-all quality remains at a high level. Last fall 299 undergraduates (sophomores, juniors and seniors) were majoring in mathematics. There were also 113 graduate degree candidates in mathematics.

Because of various heavy demands on the Department, a number of our basic junior-senior subjects taken by many of our undergraduate majors have for some years been offered in single large sections. In an effort to give more personal attention to the majors, the Department has adopted a policy of giving more of these classes in smaller sections. During the past year, for example, 18.241, Introduction to Topology, was changed from one large section to three small ones. This will be continued next year. In addition, plans have been made to schedule smaller sections next year in each of the following subjects, which have previously been offered in single large sections: 18.242, Riemannian Geometry (two sections); 18.25, Modern Algebra (four sections); 18.26, Modern Algebra (two or three sections).

Recognizing the various degrees of mathematical preparation of entering students, the Department each fall divides the freshman class into three groups. Approximately 75 of the entering students elect an honors version of first-year Calculus, 18.01S. Another 300-350 of them start immediately with the second term of the freshman mathematics program, 18.02. This leaves 500-550 who take the regular first-term calculus in the fall. The Department divides this group into three subgroups, called A, B and C sections, depending upon the mathematical background. Approximately 25 per cent of the students are placed in A sections, 50 per cent in B sections and 25 per cent in C sections. They all attend the same lectures two hours a week, but they attend different recitation sections, each meeting two hours a week. As an experiment this year, the Department has used two different sets of assignments, one for the A and B sections, and one for the C sections. This plan seems to have worked extremely well, and it will be continued next fall.

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Almost all of the full-time staff is active in research. The research is being carried out in the fields of abstract analysis, algebra, algebraic geometry, astrophysics, theory of automata and heuristic programming, differential equations, differential geometry, elasticity, hydrodynamics and applications of mathematics to magnetohydrodynamic waves, mathematical logic, number theory, numerical analysis, probability, and topology. The research activities are too numerous to mention each individually, but the work of some of the full professors serves as illustration.

Professor Prescott D. Crout has devised a bicomplex notation by defining a correspondence between bicomplex numbers and plane vectors which vary sinusoidally with time. This bicomplex notation very greatly simplifies the treatment of plane alternating vector fields, and has been applied successfully to the calculation of the $\Sigma$ and $\Delta$ antenna patterns of multiarm spiral and conical antennas.

Professor James G. Glimm's research has been in the foundations of quantum field theory. He has studied the Hamiltonian, or total energy operator, and, in certain models, has shown that it is defined and self-adjoint. A major difficulty is the presence of infinite terms in the formal expression for the total energy operator; procedures have been introduced that give rigorous meaning to these infinite terms.

Professor Sigurdur Helgason has continued working on function theory on symmetric spaces. Recently he has determined the bounded spherical functions on these spaces. In joint work with Professor Adam Koranyi of Yeshiva University, the classical Fatou theorem for harmonic functions has been extended to symmetric spaces.

Professor Bertram Kostant has continued his study of unitary representations of Lie groups, in the context of the quantization theory which he developed some years ago. He has solved a problem of long standing on the irreducibility of the principal series. Also he has extended the notion of the complementary series and the concept of the critical strip from SL(2) to all semi-simple Lie groups.

The recent research results of Professor Norman Levinson are mainly in analytic number theory. They include the summing of certain number-theoretic series, and a study of the zero-free region of the Riemann Zeta-Function near the 1-line.

Professor Chia-Chiao Lin, in collaboration with Dr. Chi Yuan and William W. Roberts Jr., continues to work on the implications of the theory of density waves on various observable phenomena in our galaxy including (1) the distribution of hydrogen gas, (2) its systematic motion, (3) the distribution of young stars, and (4) the migration of mod-
erately old stars (up to about 200 million years of age). Hydromagnetic effects are now taken into consideration. Shock formation and its implications on star formation are also investigated. Two independent determinations of the spiral gravitational field [from (2) and (4)] yield the same value of five per cent of the mean gravitational field. The pattern speed, as determined from (1), also agrees with that obtained from (4), in other words, about 11 to 13 kilometers per second per kiloparsec. Magnetic fields of the order five micro-gauss are found to have a secondary effect, somewhat smaller than that of turbulent motion. There is of course no winding of the magnetic lines in the stationary state in this density wave theory. The study of the process of star formation, as triggered by the spiral shock, removes some of the standing difficulties in this important subject. It also suggests the desirability of an extensive observational survey of interstellar clouds to determine (1) its internal turbulent motion, (2) its density, and (3) its size. All these are within the capacity of current radio telescopes.

Professor Arthur P. Mattuck has been working on isolated singularities of algebraic surfaces, obtaining, in particular, the structure of a naturally defined class of singularities which includes the so-called rational singularities, and for which the arithmetic genus equals the constant term of the local Hilbert polynomial.

Professor Franklin P. Peterson has been studying the cohomology structure of the classifying space for PL-bundles and for spherical fibre spaces. The results for orthogonal bundles are well known and have had many very useful applications during the last 15 years. It is now clear that the results for PL-theory and spherical fibre spaces will be equally useful in the years to come. He has made some progress on these problems and hopes that the complete solution will be found in the near future.

Professor Eric Reissner has continued his investigations into the foundations of the theory of elastic plates and shells. A far-reaching and generally unexpected simplification of the problem has been obtained by basing the analysis on the three-dimensional theory of a Cosserat continuum — reducing the problem to a system of first-order integro-differential equations — even for those cases in which the final two-dimensional theory is for the conventional continuum of engineering mechanics. Jointly with Professor Frederic Y.-M. Wan, new results have been obtained for symmetric deformations of shells of revolution and helicoidal shells.

Professor Gerald E. Sacks has studied measure-theoretic methods in
obtaining relative consistency proofs in set theory, and also connections
between generalized recursion theories and ramified hierarchies.

Professor Richard D. Schafer has obtained a unified theory for alter-
tnative algebras and commutative Jordan algebras. He has proved the
fundamental theorems in a structure theory, including the Wedderburn
principal theorem, for finite-dimensional "generalized standard algebras."

Professor Irving E. Segal has been studying as pure mathematics the
non-linear local function of a quantum field. By a new method, the no-
tion of normal product is developed for interacting as well as for free
fields. In the latter case, the so-called Wick products, which play a funda-
mental role in heuristic quantum field theory, are characterized and
treated in a natural and precise mathematical way, making possible a
mathematically effective formulation of the fundamental non-linear quan-
tized partial differential equations.

Professor George W. Whitehead has been studying the stable homo-
topy of various spaces (real projective spaces, finite symmetric products
of spheres) related to the bistable J-homomorphism.

PERSONNEL

In April Professor Isadore M. Singer was elected to membership in the
National Academy of Sciences.

During the past year Professors Michael Artin, Edward B. Curtis,
Levinson, Mattuck, Joseph Pedlosky, Hartley Rogers Jr. and Segal were
on leave for the entire academic year; and Professor Singer was away
for the spring term. Professor Artin spent the year at the Institut des
Hautes Etudes Scientifiques on an Alfred P. Sloan Jr. Research Fellow-
ship. Professor Curtis spent the year at the Mathematical Institute, Aar-
hus University, on a John Simon Guggenheim Fellowship. Professor
Levinson spent part of the year in Israel and the remainder in this area.
Professors Mattuck and Segal spent the year at Brandeis University, Pro-
fessor Segal on a Guggenheim Fellowship. Professor Pedlosky was at
Imperial College, University of London, on a Sloan Fellowship. Professor
Rogers spent the year at the University of Cambridge on a National Sci-
ence Foundation Senior Postdoctoral Fellowship. Professor Singer spent
most of the spring term in this area.

The Department was fortunate to have Dr. Seymour A. Papert, and
Professor Shoichiro Sakai of the University of Pennsylvania, with us as
Visiting Professors during the year; Professor Donald C. Spencer of
Stanford University as Visiting Professor during part of the fall term; and
Professors Solomon Feferman of Stanford University and Alistair H.
Lachlan of Simon Fraser University as Visiting Associate Professors,
Professor Feferman for the year and Professor Lachlan for the fall term. Professor Papert's visit is continuing into the next year. Professors Leonard Gross of Cornell University, Tseng-Yuh Lee of National Tsing Hua University, and Robert R. Stoll of Oberlin College spent the year with us as Guests.

Our Department is pleased to report that Professor John W. Milnor of Princeton University will be joining our faculty next year as Alfred P. Sloan Professor of Mathematics, and Professor Elliott H. Lieb of Northeastern University as Professor of Applied Mathematics. Other new faculty members joining our faculty are Associate Professor Harold M. Stark, whose appointment starts with the spring term and Assistant Professor Colin J. Thompson.

The Department regrets to report that Professor Pedlosky and Professor Theodore W. Gamelin have resigned to accept Associate Professorships, Professor Pedlosky at the University of Chicago, and Professor Gamelin at the University of California at Los Angeles. Professor Thomas J. Lardner is transferring to the Department of Mechanical Engineering at M.I.T.

Professor Reissner was awarded a National Science Foundation Senior Postdoctoral Fellowship for next year, and Professors Singer and Takeshi Kotake John Simon Guggenheim Memorial Fellowships.

The Department is very fortunate in that Professor Levinson has accepted appointment as Head of the Department effective with the academic year 1968-69. In addition to his distinguished research achievements, Professor Levinson over the years has been a strong influence in the development and work of the Department. Working closely with Professor Levinson will be Professor Harvey P. Greenspan as Chairman of the Committee on Applied Mathematics, Professor Kenneth M. Hoffman as Chairman of the Committee on Pure Mathematics, and Professor Daniel B. Ray as Executive Officer.

WILLIAM T. MARTIN

DEPARTMENT OF METEOROLOGY

The year has been one of satisfying progress in education and research. In common with other departments here and elsewhere we are becoming increasingly concerned about the future impact of research funding stringencies and the new Selective Service regulations. It seems reasonable to anticipate some reductions next year both in research funds and in the number of students, although present projections do not yet reveal
these decreases. The number of applicants for admission and the number accepted were much the same this year as last but it remains to be seen how many of them will be here in September.

It is my impression that Federal research funding policy will place increasing emphasis on areas that contribute rather directly to the solution of current national problems. Although the merits of this policy may be debatable, it is relatively favorable for research in meteorology and oceanography. The limitations of the natural environment are becoming increasingly evident in such manifestations as air pollution and shortages of fresh water. Exploitation of the resources of the oceans is being proposed widely as a necessary supplement to the food and mineral resources of the continents. Solutions to problems of this sort depend heavily on more complete knowledge of the atmosphere and the oceans.

Aside from natural scientific curiosity, our primary motivation, the principal application of meteorology has been and continues to be the forecasting of weather. More recently the modification or control of the weather has become of increasing interest. It is fortunate that progress towards such applications follows much the same course as that pursued in the search for a more complete scientific understanding of the atmosphere. For some years now, mathematical models have been constructed on the basis of the governing equations, simplified by assumptions derived from observational experience. Such models are now used with considerable success for forecasting up to three days in advance. It now appears that further substantial progress in the development of such models is dependent on more complete observational data over the entire globe and on the incorporation of more realistic representations of the boundary layer phenomena, radiative exchange processes, the release of latent heats and the effects of smaller scale circulations. By and large the atmospheric models have been developed in the context of the middle latitudes, and it is becoming clear that the phenomena in the tropical atmosphere, covering half the globe, differ in important respects that demand careful study. Except for the collection of global data which is being undertaken on an international basis through the World Weather Watch, the research of the Department in meteorology is concerned with the problems discussed above. The ultimate incorporation of these additional factors and of global data into an atmospheric model will pose very formidable computation problems. It has been estimated that the integration of such a model in less than real time, as required for a useful forecast, will require the nearly exclusive use of a future-generation computer.

The above discussion might imply that the only real limitations on the period ahead for which it is possible to forecast are sufficient observa-
tional data and the construction of a model containing all the important effects. Research in the Department strongly suggests that this is not really true. It appears that the atmosphere never returns to any given initial state; that is, it is basically non-cyclic. If this is true, it follows that two initial states differing by any arbitrary amount, no matter how small, will eventually diverge into entirely different forms. The initial small difference between the atmosphere and the model may result from the inevitable observational errors or from circulations too small in scale to be sensed by the observational grid. The crucial question of how long an ideal model and the real atmosphere will stay in step does not yet have a definitive answer although estimates ranging from a week to a month or more have been made. Another type of limit may be set by solar variability.

Research in oceanography has turned more towards the study of smaller time and space scales. This has revealed, not unexpectedly, that the ocean and its circulations are not in a steady state. Wave motions ranging from very long period tides to Rossby waves and shorter internal waves appear to be important features. New and more sophisticated instrumentation is being developed to study such phenomena and modern techniques of data analysis are required to extract the pertinent information from the complex records.

The joint graduate program in oceanography with the Woods Hole Oceanographic Institution was officially launched at a dockside ceremony at Woods Hole on May 8. The joint program was, in fact, well under way before the ceremony and there will be some 40 students enrolled in it next fall. About half of them will be registered in this Department and the others in the Department of Geology and Geophysics. A number of our students and faculty will spend the summer at Woods Hole on research and as participants in the first formal courses to be given at Woods Hole under the joint program. Some of the subjects of instruction will be given by our staff and some by Woods Hole staff. All of the subjects are listed in the M.I.T. Catalogue and carry regular academic credit.

We were pleased to have two visiting faculty members with us during the year. Professor G. Amos Eddy of the University of Texas was Visiting Associate Professor during the fall term. Dr. Lewis D. Kaplan of the Jet Propulsion Laboratory of the California Institute of Technology, and a former member of our staff, was a Visiting Professor in the Department of Meteorology and in the Department of Geology and Geophysics during the spring term.

An event of some note in the history of the Department was the re-
DEPARTMENT OF NUTRITION AND FOOD SCIENCE

tirement of Professor Hurd C. Willett. Professor Willett joined the faculty in 1929, only a few months after the late Professor Carl-Gustav Rossby established the first professional course in meteorology at M.I.T. Thus Professor Willett's service has spanned almost the entire history of meteorology at M.I.T. as a field of specialization and he has contributed greatly to its growth both in education and in research.

Members of the faculty continued to serve on a variety of committees and boards of various governmental agencies and professional societies.

HENRY G. HOUGHTON

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

CURRICULUM DEVELOPMENT

Department curricula have been undergoing careful and continuing re-examination.

A major reorganization has taken place in the teaching of food engineering, food processing, and food technology; that is, in the area of subjects dealing with quantitative and engineering aspects of the overall program. It has been evident for some time that subject sequences available in the School of Engineering do not provide a satisfactory course for graduate students in food science and technology whose specialization is not in engineering. Accordingly, a new senior subject, 2.642J - 20.13J, Food Engineering, was developed which, with the thermodynamics subject taught by Professor August L. Hesselschwerdt Jr. (2.641), will constitute the minimum engineering requirement for food science and technology students.

The availability of a new engineering pilot plant and the reorganization of the undergraduate curriculum with respect to the separate food science and technology and nutrition requirements permitted the reorganization of laboratory subjects. The undergraduate food science laboratory subject, 20.111, was dropped, and the laboratory part of 20.52, Advanced Food Technology, eliminated. The advanced subject, 20.52, will now deal more deeply with theoretical aspects of food processing. A new laboratory subject at the graduate level, 20.12, was authorized. This subject will be taught by Professors Theodore P. Labuza and Steven R. Tannenbaum and will deal with chemical and physicochemical aspects of food processing. As a result of these changes, the content of Advanced Food Engineering, 20.15T, will also change. It will be devoted to special projects in modern food engineering.
The program in nutritional biochemistry and metabolism has been oriented to attempt to understand the way in which the diet, as part of a complex environment, regulates and controls metabolic function and adaptations. Since its initiation, the major goal of this curriculum has been to provide individuals trained to understand nutrient utilization at the most fundamental levels. In other words, the knowledge and techniques of molecular biology have been taught jointly with those of physiology and physiological chemistry to attempt to produce a graduate who understands the functioning of the mammalian organism and the way it adapts to environmental changes. Since there is a multitude of paths that the student may follow, the faculty responsible for the nutritional biochemistry and metabolism degree program have supported a flexible curriculum that allows the individual student, his advisors, and committee to decide on the direction of study. The common emphasis is on biochemistry and mammalian biology.

To fill the needs of the program, three new subjects have been offered this year. The first, 20.31, Advanced Nutritional Biochemistry and Metabolism, is administered by Professor Hamish N. Munro and is taught by him and members of the staff. It was designed to provide a framework for consideration of advanced knowledge in the areas of adaptation and response to dietary variations. The second, 20.37, Endocrinology, is administered by Professor Leslie J. DeGroot and is taught by him and a series of guest lecturers. This subject was needed to provide fundamental knowledge in the area of mammalian regulatory activity. Finally, Professor Richard J. Wurtman developed 20.80, Neuroendocrine Control Mechanisms, which provides information in another aspect of regulatory phenomena, specifically the interaction of the nervous and endocrine systems. During the next year, Professor Edwin D. Bransome Jr., with the participation of several other members of the faculty, will offer a subject in mammalian physiology. This is an absolute requirement in our program, since the material offered by the Department of Biology in this area does not cover the basic knowledge of systemic physiology required by our students.

The student of our present Nutrition and Food Science curriculum should be one who acquires a sound understanding of the functioning of the mammalian organism and its response to environment, with special knowledge of nutritional biochemistry and metabolism.

In biochemical engineering, as a result of their direct contacts with industrial problems, Professors Richard I. Mateles and Daniel I. C. Wang felt that it would be beneficial if the subject related the theoretical material to actually existing problems. This was accomplished by intro-
ducing a plant or process design problem as a six-week segment of the laboratory, replacing three experiments. This has proved useful in introducing the students to notions of economics and developing in them the judgment whereby an engineer selects from among the possible means of producing a commodity, the best and least costly one. Another change which has been introduced over the past two years has been an increase in the attention given in 20.47 and in the research programs to problems of recovering substances and products from fermentation systems.

RESEARCH PROGRAMS

FOOD SCIENCE AND TECHNOLOGY

The faculty involved in research activities in food science and technology have often been classified according to subdisciplines such as food microbiology, food engineering, and food chemistry. Any serious review of the major research activities as well as of the teaching activities, reveals immediately that such subdivisions are artificial. Not only are individual faculty members involved in a variety of projects from various disciplines, but most of the food science and technology faculty are recognized as professional leaders in more than one discipline.

The guiding principle of the field of food science and technology is the combination of biological, chemical, physical, and engineering principles in scientific study of foods. M.I.T.'s research program has always been particularly devoted to this principle, and the present research does, in fact, reflect this interplay of various disciplines in specific projects.

Much of the important work in the chemical and physicochemical area is devoted to the understanding and control of changes which occur in foods during processing and storage. Our approach has been to try to understand the basic mechanisms, chemical and physical, which underlie these changes. Model systems are often employed, but in every case the ultimate applicability to actual foods is the objective firmly retained in the endeavor. Some of the specific problems in this area include: oxidative, hydrolytic, and browning reactions in dehydrated foods; the role of organic volatiles active as flavors in food processing operations; and the mechanisms underlying adsorption and desorption of volatile organic compounds in various operations including desolventizing of FPC, freeze drying of fruits, smoke curing of meats, and many others.

Other examples could be cited, but these illustrate the type of approaches to problems in food chemistry in which M.I.T. has been active.

In the area of quantitative aspects of foods, including food engineering as well as some aspects of chemistry and microbiology, the faculty
have had an equally distinctive approach. Their particular interest has been in the influence of food properties and of food composition on the engineering aspects of food preservation and in particular on mass and heat transfer.

Some examples of research projects in which M.I.T.'s research group has exercised leadership are: dielectric properties of food and the role of these properties in microwave processing of foods; the influence of surface and capillary properties of foods on mass and heat transfer in dehydration; the role of thermal and diffusional food properties in various food operations, including dehydration and evaporation; and the role of diffusional properties of packaging in controlling internal environment of foods.

Food microbiology and virology research is primarily concerned with the effects of various food-processing operations on the behavior of microorganisms in foods, under stress conditions, in an effort to understand the basic mechanisms of bacterial resistance.

Microbiological research on the applications of ionizing radiation as a food-processing tool include irradiation of poultry and fish meal to eliminate salmonellae and the ability of \textit{Cl. botulinum} Type E to produce toxin in irradiated fish. This work includes studies of microbial interactions and microbial population shifts.

The microbiology of freeze-dried foods has centered around the influence of the drying operation on the survival of a variety of microorganisms and alterations in the microbial flora of a food product. Investigations on the behavior of viruses in sublethally processed foods is now being initiated.

The biochemical engineering program has been oriented towards studies on continuous culture in an effort to elucidate the kinetics of substrate uptake by pure and mixed cultures when presented with several carbon sources simultaneously; on the pathway of biosynthesis of aflatoxin in collaboration with Professor George H. Buchi of the Department of Chemistry. Studies on single-cell protein are also continuing and they will be expanding this coming year as a result of a grant from the Alfred P. Sloan Foundation. In addition, studies on methods of recovery of microbial cells from fermentation broths and on the use of ultrafiltration membranes as a means of concentrating and purifying biological active substances are also continuing.

**NUTRITIONAL BIOCHEMISTRY AND METABOLISM**

The thrust of research in the nutritional biochemistry and metabolism group is concerned with metabolic control and regulation or, more
specifically, adaptation to environment. This work is conducted as required at the subcellular, cellular, tissue level, or organ level. Moreover, it is being extended to the human subject or patient in appropriate clinical investigations.

At the subcellular level, the regulation of protein metabolism is the area of greatest concentration. Ranging from studies of the nutritional and hormonal factors influencing protein metabolism to studies of the mechanisms regulating protein synthesis and turnover, these studies have as their goal the elucidation of the control mechanism in protein use. The manner in which toxic components of the environment modify protein synthetic mechanisms is also under study. In a similar area, work is being performed to determine the mechanism by which protein synthesis is developed in the neonatal rat; that is, the mechanisms by which specific tissues determine their protein needs during their development. The way in which vitamins and other cofactors modify regulation also is being studied.

In addition to protein metabolism, other aspects of environmental effects on metabolism are being examined at the cellular level. The environmental modification of specific enzyme cycles is being studied with particular reference to tyrosine transaminase. The development of this enzyme cycle in neonatal rats is also under investigation. The interaction of environment and metabolism is being explored through work on endocrine and neuroendocrine mechanisms regulating this relationship.

Less specific studies are also in progress at the tissue and organ level. For example, the consequences of pre- and post-natal vitamin deficiencies and of protein and calorie deficits in the rat are under investigation. The effect of diet on tissue structure and composition is a related concern. The relationship between dietary factors and the development and resistance to disease of the teeth and soft tissues of the oral cavity is a major study area.

At the clinical level, the influence of environmental variables, such as infection, psychological stress, and muscular exercise, on metabolism and nutrient requirements is under study. The determination of individual variation in nutrient requirements is an expanding program.

In addition to the major areas of adaptation and regulation outlined above, there are two other general program areas of interest. In the first, development in the mammal during the perinatal and neonatal periods is under investigation. These studies include not only the work on protein metabolism and enzyme cycle initiation, discussed earlier, but also research on the role of diet in the development of these mechanisms and on the development specifically of the oral structures. Similar re-
search on the effect of vitamin deficiency during the pre- and postnatal periods is also in progress. This work is closely related to the theme of the three-day International Conference on Malnutrition, Learning, and Behavior organized by the Department last year, the proceedings of which have now been published.

The second area is concerned with alleviation of nutrient deficiencies throughout the world. This area utilizes the broad talents available in the Department. In cooperation with the food science and technology and biochemical engineering faculty, studies have ranged from those concerned with the biological utilization and safety of fish protein concentrate and single-cell protein to those involved in the development and evaluation of synthetic sources of dietary energy. At the clinical level, human volunteers have been employed to determine the nutritional value of fish protein concentrate and single-cell protein with and without amino acid fortification. Human subjects have also participated extensively in studies exploring possibilities of increasing protein supplies by diluting high-quality protein with low-cost non-specific sources of nitrogen.

It is apparent that research in nutritional biochemistry and metabolism is multifaceted and broadly interdisciplinary. It ranges from relatively purely academic studies to studies readily applicable to solving the world food needs. Throughout, however, runs the common thread of an attempt to understand how the mammal relates to its ever-changing environment and how this knowledge can be put to use in meeting man's need for food to ensure optimum health and longevity.

One of the problems facing research programs in general is the tightening up of research funding in a number of areas. Although this Department has not yet been affected seriously in terms of existing projects, there is no question but that new research proposals and renewal requests will be affected. There is special concern for younger faculty members submitting their first grant requests.

INTERNATIONAL COLLABORATION

Because of the very nature of its work and its role in society today, the Department has been active in collaboration on an international scale both in terms of departmental research activities and the activities of individual faculty members. In addition, the Department receives many requests for admission from foreign students throughout the world and accommodates as many of the superior applicants as space, funds, and facilities will permit.

Two large-scale departmental research and teaching programs are active. The first, initiated with the departmental expansion of 1961, is
a close working relationship with the Institute of Nutrition of Central America and Panama (INCAP) which has made it possible to offer subjects in Guatemala with the assistance of the senior INCAP staff. This contributes greatly to the experience and understanding of physicians and dentists regarding problems of clinical nutrition, public health nutrition, and the evaluation of nutritional status. Moreover, it has provided an excellently equipped and supervised facility for students who wish to work with malnourished human patients as part of their thesis research. This relationship is to be maintained and strengthened by the planned participation of several members of the food science and technology faculty as well as the continuing cooperation of members of the nutritional biochemistry and metabolism faculty. This association with INCAP, an outstanding teaching and research institute of international reputation located in Guatemala City, is a valuable asset to the Department's teaching program and gives excellent field opportunities to students and faculty.

A second and more recently established activity is based in Bangkok, Thailand, in cooperation with the University of Medical Sciences in Bangkok and the University of Minnesota. The program is directed by Professor Gerald N. Wogan with the support of a contract sponsored by the Malnutrition Panel of the U.S.-Japan Cooperative Medical Science program. Professor Ronald C. Shank is resident in Thailand, with responsibility for the field activities in Southeast Asia and as supervisor of the laboratory in Bangkok.

The laboratory has been set up to determine the frequency and extent of aflatoxin contamination and of previously unrecognized mycotoxins in feeds and foods in Thailand and neighboring countries. With the participation of Professor Halvor N. Christensen of the University of Minnesota, the number and kind of fungi in foods and feeds is being determined as well as the conditions of harvest, transportation, and processing under which the toxin is elaborated and prevented. In the program, some of the basic information developed by Professor Wogan and Professor George H. Buchi of the Department of Chemistry is being put to practical use in the field. Moreover, new toxins found in Southeast Asian foods will be isolated and identified through the Wogan-Buchi cooperation.

In addition to the above, individual faculty members have also participated a great deal in international activities which should result in furthering the common good of mankind. This is, to a large measure, because this Department, like any other concerned with one of man's basic needs, has an important role to play in this era of rising expectations. Thus it has a potential for becoming a determinant of man's future.
THE ROLE OF THE DEPARTMENT IN SOCIETY

The paragraph above should not be construed to indicate that the Department has an important potential only in the lesser developed countries where malnutrition and undernutrition are endemic and where food conservation is badly needed. On the contrary, there is much to be done in learning more about the diseases of affluence and how to prevent them.

Another important role in society emerging for the Department deals with nutrition and the urban crisis. Nutrition and food in the city ghettos become as important as the other necessities of life—including shelter, clothing, and good schools—and closely interwoven with them. The Department is seeking funds to study, on an interdisciplinary basis, the nutritional status of people in low-income urban areas such as parts of Cambridge and the South End of Boston. This fits into the larger interest of M.I.T. in urban problems.

Scientific and technical knowledge relating to food and nutrition is increasing steadily. Members of our faculty hope to continue to respond effectively to the challenges of our times by providing personal leadership and training students to meet and solve the problems of food supply and human nutrition in a rapidly increasing population with rising expectations.

EXTRADEPARTMENTAL COOPERATION AND ACTIVITIES

The Department's role in administering the degree in biochemical engineering jointly with the Departments of Chemical Engineering and Biology as well as its administration of the Clinical Research Center have been covered in earlier reports.

More recently, the Department not only has developed single-cell protein research on a very broad multidisciplinary basis within the Department, but also has planned for the participation of faculty and students from the Sloan School of Management and Department of Economics at an appropriate stage. Faculty of the Department are also actively participating in the program of the new M.I.T. Center for Space Research and have been assigned laboratory and office space in the new Space Center building dedicated on April 25, 1968.

NEVIN S. SCRIMSHAW

DEPARTMENT OF PHYSICS

Last year degrees given by the Department of Physics included 104 Bachelor's, five Master's, and 38 doctor's.

The year saw the completion of the Center for Theoretical Physics,
on the north end of the third and fourth floors of Building 6. The architectural design of the Center has actually added space for theoretical work without impeding to any great extent the flow of corridor traffic. The beautiful new quarters will have a stimulating effect on the productivity of our physicists and add to the significant position of M.I.T. in theoretical physics.

The Center was dedicated during the week of March 18, jointly with the Center for Advanced Visual Studies, and a number of distinguished theorists, including many from abroad, attended the exercises. Addresses were given by Edwin E. Salpeter; Julian S. Schwinger, Nobel Laureate; Tsung-Dao Lee, Nobel Laureate; Hans A. Bethe, Nobel Laureate; Gerald E. Brown; and Murray Gell-Mann.

The most pressing need in the Department for the past ten years has been a reading room with reference books and periodicals for the use of the faculty, but primarily for the use of the graduate students. Presently the unassigned graduate students have literally no place to sit, and we feel the time to integrate new students into the Department will be appreciably shortened by the existence of an adequate reading room. Plans for a new physics building, hopefully to be completed by 1973, are beginning to evolve. The coming year will see the renovation of 6-120, the medium-sized (180 seats) physics and chemistry lecture room necessary to our upperclass and graduate teaching.

**UNDERGRADUATE PHYSICS**

For the first time, the Department is offering two distinct first-year subjects, either satisfying the Institute requirement. The regular 8.01 and 8.02 will follow the pattern set and revised by Professor Anthony P. French. The new 8.011 and 8.021 is being developed by Professor Robert I. Hulsizer Jr. This subject will in no sense be a subdued or degraded version of the regular subject. Rather, it is different. It will be more philosophical than mathematical in its approach to the subject and will be pointed towards students whose major course of study requires only one year of physics. However it will be quite feasible to follow 8.011 or 8.021 with either 8.02 or 8.03 if the student’s plans change.

It has been the desire of the Department (and certainly of many students) to involve interested students in active physics laboratory work at an early period. In order to allow the student to receive credit while pursuing such work, credit hours have been arranged in 8.18T (formerly 8.12). This has been used for some time as a credit relationship between individual students and faculty members. Last year a group extending in background from freshmen through fourth-year graduate students met
regularly in order to involve students at all stages of development in physics. Professors Rainer Weiss and Albert G. Hill, who organized the program, considered it quite successful and, by request of the students, are continuing it next year, hopefully with two or three new freshman members.

The upperclassmen have independently approached the problem another way. They have asked that in the freshman and sophomore years in particular, students be attached as part-time assistants to graduate students both to help the graduate student and to learn in so doing. This has been tried on an informal basis by the students and will be made somewhat formal this fall by giving credit for it, again through the use of subject 8.18T.

Freshmen electing physics as a major subject have increased in number by 40 per cent over this period a year ago, which may indicate that we are succeeding in reaching the undergraduate better than formerly.

RESEARCH

Most of the research in the Department is reported separately in the reports of the research laboratories and centers such as the Laboratory for Nuclear Science, the Francis Bitter National Magnet Laboratory, the Center for Materials Science and Engineering, and the Research Laboratory of Electronics. An important exception is the work of Professor Ali Javan and his associates, Professors Abraham Szöke, Gerd Koppelmann and Michael Feld, in the field of optical and infrared lasers.

This group is engaged in research on fundamental problems in quantum electronics and modern precision spectroscopy. Emphasis is placed on the development of techniques to explore new aspects of the interaction of coherent electromagnetic radiation with matter. Research areas include: high-resolution studies in which non-linearities of atomic and molecular resonances are utilized in achieving significant narrowing of the spectral line profiles; extension of microwave frequency mixing and absolute frequency measuring techniques into the far-infrared and infrared ranges—an area of considerable importance in establishing an ultimate connection between the standards of time and length; precision determination of fundamental constants, including the speed of light; laser magneto-optical spectroscopy of solids in the infrared; high-resolution studies of ultraviolet gas laser transitions and mechanisms; and studies of molecular energy transfer and relaxation processes in the infrared region.

In the field of high-energy physics, Professor Sergio P. Fubini's work in the field of elementary particles and dispersion theory has been re-
warded by the Heineman Prize. Professor Steven Weinberg’s formulation of a theory of low-energy pion processes has furnished particle theorists with a new probe of the strong interactions. Professor Weinberg’s results hold exactly at the non-realistic pion mass of zero, but Professor Fubini has succeeded in generalizing Professor Weinberg’s theory so that it holds for pions of finite mass. On the experimental side, Professor Samuel Ting’s work at Deutsches Elektronen-Synchrotron (DESY), Hamburg, on tests of quantum electrodynamics and meson photoproduction, and the work of Professors Henry W. Kendall and Jerome I. Friedman at and jointly with Stanford University on nucleon structure are worthy of note.

In nuclear physics, major accomplishments have been an increasingly quantitative understanding of nuclear spectra and the development of a new understanding of the rotational model for nuclei. This now permits the calculation of the moment of inertia and other parameters from first principles. The method involved can be used for any redundant variable and is now being applied to the calculation of the effects of recoil in nuclear reactions.

On the experimental side, Professor Lee Grodzins’ group has made measurements of the magnetic moments of vibration-like states utilizing the very high hyperfine magnetic fields of these nuclei imbedded in a ferromagnetic lattice. These measurements were made by implanting the target nuclei into iron, cobalt or nickel hosts by recoil following Coulomb excitation. In the course of these experiments an interesting observation emerged, that nuclei moving with recoil velocity greater than $10^8$ centimeters per second through the host lattice see a magnetic field which is totally different, both in magnitude and sometimes even in sign, from the static hyperfine field. This transient field has been observed to exist for less than $10^{-12}$ seconds, the approximate time for the ion to slow down in the lattice, and has a magnitude which increases with the mass of the implanted ion, up to about 20 megagauss for platinum recoiled into iron. A probable mechanism for this effect is the pickup of polarized d electrons by the recoiling ion as it neutralizes in the host lattice.

This year saw the start of construction of a 400-MeV electron accelerator, a most up-to-date tool for the study of nuclear phenomena. A number of our physicists are preparing experiments for this unusual machine when it is completed in 1970.

In the field of non-optical astronomy, Professor Bruno B. Rossi and his collaborators, Professors Alan H. Barrett, Hale V. Bradt, Bernard F. Burke, George W. Clark, Walter H. G. Lewin and James W. Overbeck, have made several significant advances. A great deal of new information
in X-ray astronomy has been forthcoming, and the identification of these X-ray sources and their correlation with radio and optical sources have been made. In the radio frequency spectrum, by the use of the technique of phase-coherent interferometry (using baselines as long as 5,000 miles), position and size of OH radio sources have been measured, with angular resolutions far exceeding any before attained in astronomy.

Many of the developments in non-optical astronomy carry important implications for optical astronomy which must be followed up by those equipped with optical telescopes. The importance of this correlation points up the need for greater effort by M.I.T. in the optical astronomy field.

In the general field of solid-state and atomic physics, many results of consequence have been obtained during the past year. Space permits only the mention of the use of molecular gas lasers to investigate novel quantum magneto-optical phenomena by Professor Benjamin Lax and his colleagues. In addition, work is proceeding on extending our solid-state knowledge through cyclotron resonance experiments. Professor John G. King and his group, in extending molecular beam techniques to very low temperatures, have continued to study the mechanism of atoms evaporating from liquid helium.

Professor George B. Benedek's group has begun a new field of activity in the field of biophysics. Using sophisticated techniques of optical mixing spectroscopy, they are able to resolve with precision the extremely narrow spectral distribution in laser light scattered from a solution of biological macromolecules. The spectral width and shape provides information on the diffusional motion of the macromolecule, and serves as an accurate measure of the changes in molecular size and shape that accompany changes in the biological function of these molecules. This form of experimentation promises to be fruitful for the study of denaturation of macromolecules, for the precise measurement of molecular weights of heavy macromolecules, and for the detection of internal modes of vibration.

PERSONNEL

During the coming academic year Professors Aron M. Bernstein and Sanborn C. Brown will be on sabbatical leave for the entire year, and Professors Barrett, Martin Deutsch and Harald A. Enge will be on sabbatical for one term. During this same period the Department will have a number of visiting faculty members. Dr. Isador I. Rabi, Nobel Laureate and University Professor Emeritus at Columbia, will be Karl Taylor Compton Visiting Professor of Physics. Professor Wayne A. Bowers, on
DEPARTMENT OF PHYSICS

leave from the University of North Carolina, will join us as Visiting Professor and will be associated with the Education Research Center; Professor Kurt Gottfried of Cornell University will be Visiting Professor affiliated with the Center for Theoretical Physics; Dr. Gene A. Baraff, on leave from Bell Telephone Laboratories, will be Visiting Associate Professor and will be working with our plasma group in the Research Laboratory of Electronics; and Dr. Peter Schofield of the Atomic Energy Research Establishment, Harwell, U.K., will be Visiting Professor for the first term in the Center for Materials Science and Engineering. Professor Weinberg will remain for another year as Visiting Professor in the Theoretical Center.

Professor Fubini, Visiting Professor during the 1967-68 academic year, has been appointed Professor in the Department and will join our faculty as a permanent member with the start of the fall term. Also appointed Professor is Dr. Bruno Coppi, presently at the Institute for Advanced Studies. Dr. Coppi will take up his new duties here in February.

Other new faculty members who will join our department are: Assistant Professors William K. Bertram, James R. Clow, Michael S. Feld, Richard C. Lanza and Kosta M. Tsipis, and Instructors Dr. Thomas K. Gaisser, Dr. Keith F. Ratcliff and Dr. Chia-Gee Wang.

Professor Thomas H. Dupree, who has been a faculty member in the Department of Nuclear Engineering since 1961, will henceforth hold a dual appointment as Associate Professor in the Departments of Physics and Nuclear Engineering.

The following received promotions as of July, 1968: to Professor, George Bekefi, William Bertozzi, Icko Iben Jr.; to Associate Professor, Hale V. D. Bradt, John B. Bronzan, Walter H. G. Lewin, Richard K. Yamamoto; and to Assistant Professor, Wallace M. Manheimer.

One member of our faculty, Professor Nathaniel H. Frank, retired this year but will remain in the Department as Senior Lecturer. About 35 years ago, when the Department of Physics was completely turned around at M.I.T., on the occasion of the arrival of Karl T. Compton as President and John C. Slater as Department Chairman, Professor Frank was given the task of revamping the first two years of physics. He completed this task in 1938, and his work set a long-time standard both for this Department and for many, many other scientific institutions. It is true that in the past five years we and others have departed somewhat from the Frank texts, but the tradition and the intellectual impact of Professor Frank himself are still with us.

Professor Frank, Head of the Department of Physics from 1952 to 1962, has had an uninterrupted association with M.I.T. for nearly half
a century. He came to the Institute first as an undergraduate and received
the S.B. degree in 1923 and the Sc.D. degree in 1927. Prior to his long
association with the Department of Physics, he spent a year (1923-24)
as an assistant in the Department of Electrical Engineering. He became
a Research Associate in physics in 1924-25, an Instructor in 1925,
Assistant Professor in 1930, Associate Professor in 1937 and Pro-
fessor in 1944. He was the Department's Executive Officer from 1949
to 1951 and Acting Head of the Department in 1951. His particular
areas of interest have been theoretical physics and metallic conduction.
He studied in Germany in 1929-30 and at the Institute for Advanced
Study at Princeton, New Jersey, in 1935. His wartime service was di-
vided into two phases. He made important contributions in radar
theory and development at the M.I.T. Radiation Laboratory between
1941 and 1943, then went to Washington as Expert Consultant in the
Office of the Secretary of War. During the 1950's, Professor Frank was
among those active with Professor Jerrold R. Zacharias in the develop-
ment of the PSSC physics curricula for the nation's high schools. In re-
cent years he has been associated with the Education Research Center
and is primarily concerned with the reconstruction and improvement of
vocational, technical and occupational education in American schools.
He is the author of two introductory texts in physics and co-author with
Professor John C. Slater of Introduction to Theoretical Physics. He is a
Fellow of the American Academy of Arts and Sciences and the American
Physical Society and a member of the American Association of Physics
Teachers.

VICTOR F. WEISSKOFP
The Provost's office has particular responsibility for the interdisciplinary laboratories which span more than a single school and for the coordination of those academic activities which are similarly broad in character, such as the planning of the undergraduate core curriculum, the experimentation with the educational process, the rapidly developing effort in urban studies, and the biomedical science and engineering program. The Provost's office also has jurisdiction over several interschool activities including the joint Harvard-M.I.T. Electron Accelerator and the Northeast Radio Observatory Corporation.

In previous years we have reported with much satisfaction the growing faculty interest in educational improvement and reform. This trend has continued during the past year. Since the report of the Committee on Course Content Planning, whose recommendations were adopted by the Faculty in 1967, there has been a steady evolution of the undergraduate subjects and programs, necessitating much interdepartmental and interschool coordination and supervision. Though the responsibility for individual subjects has remained in the hands of the individual academic departments, there has been an extensive and continuing endeavor to interrelate them more effectively. At the same time, there have been efforts to relate the course content more closely to the various career interests of students, and also to adjust the subject matter to the fact that most of the students now entering M.I.T. are better prepared than they were a few years ago because of improvements that have taken place in high school science and mathematics courses.

The intense interest and activity in our course content development has stimulated the Faculty to search for more effective teaching methods as well, resulting, not surprisingly, in an increasing number of experi-
mental classes and other academic innovations. Among the latter are a number of experiments incorporating students into research activities and into "family groups," which bring together students of varying degrees of maturity and experience with one or more faculty members. There has also been exploration of highly concentrated study experiments that permit students who desire to do so to concentrate on one subject at a time at a greatly accelerated pace. Plans are being made for a faculty-student working group that will spend next year exploring means whereby students could be given a much higher degree of intellectual autonomy, that is, the freedom to set their own pace and to have a greater voice in the selection of their academic path during their four years at the Institute. Current plans call for the working group to spend the fall term developing plans for an experimental program, with the hope that it can be implemented shortly thereafter. These and other academic innovations and experiments are under the policy supervision of the Committee on Educational Policy, the Provost's office having responsibility for the actual administration of the programs. Two years ago the Faculty created the position of Undergraduate Planning Professor, a post to be held by a member of the Faculty, whose responsibility it would be to coordinate and monitor the core curriculum developments. This position is associated with the Provost's office for administrative purposes. Professor George E. Valley, who served as the first Undergraduate Planning Professor, played a key role in the effective development of some of the new core subjects, insuring the necessary degree of coordination and an equitable balance of work load between them. He also served as an "academic ombudsman," representing the student interest with regard to various aspects of the core subjects and the freshman year in general. Professor Edgar H. Schein of the Sloan School of Management has been elected to the position of Undergraduate Planning Professor for the next two-year term.

The position of Assistant Provost was created during the past year and Professor Paul E. Gray was appointed to the position. The Assistant Provost will have responsibility for the many matters relating to educational innovation and curriculum development which impinge upon the Provost's office. With freedom to concentrate on the academic problems of the undergraduate program and with his highly relevant background as a distinguished teacher, former Chairman of the Freshman Advisory Council, and former Associate Dean of Student Affairs, Professor Gray is expected to contribute greatly to M.I.T.'s efforts to improve its learning environment.

The current year has also seen the initiation of two precedent-breaking
cooperative programs with neighboring institutions: the Wellesley-M.I.T. Undergraduate Exchange Program, and the joint graduate program between M.I.T. and the Woods Hole Oceanographic Institution.

The exchange program with Wellesley makes available to the students and faculty of both schools the curricula and facilities of each. Although the program was scheduled to start at the beginning of the next academic year (September, 1968), four students inaugurated the program during the fall term of 1967. During the spring term of 1968, 48 students participated in the program, and it is expected that this fall the number will increase to 150 students, divided equally among the two schools. The choices of subjects — Astronomy, History, Chinese, English, and Sociology for M.I.T. students, and Architecture, City and Regional Planning, and Humanities for the Wellesley students — indicates that the students are indeed using the program to broaden their range of academic experiences.

After several years of intensive planning, the Woods Hole Oceanographic Institution and the Department of Geology and Geophysics at M.I.T. have developed plans for a joint graduate program in oceanography. The program, announced by the presidents of the two institutions on May 8, 1968, brings together teaching resources and research facilities to create a graduate study program in oceanography of the highest caliber. A companion program in ocean engineering is also being developed. An Education Committee appointed by the presidents of the two institutions has over-all responsibility for the program, and direct supervision is provided by the Dean of Graduate Studies of the Woods Hole Oceanographic Institution, a position created specifically for this purpose. Dr. H. Burr Steinbach, former Chairman of the Department of Zoology at the University of Chicago, has accepted this position.

The M.I.T. Faculty and student body share the widespread determination of Americans to help black America obtain its rightful place in the society, and toward this goal have undertaken a number of special projects designed to permit black youth and members of other underprivileged minority groups to have access to more adequate educational opportunities, including an M.I.T. education. Among these programs are student-operated tutoring programs in the Cambridge community, a student-sponsored program in which M.I.T. students teach in the Rindge Technical School in Cambridge, and a faculty-sponsored Upward Bound Program for youngsters in the part of Cambridge neighboring the M.I.T. campus. Dr. Louis Menand III has joined the M.I.T. staff to assist in the operation of these programs and to help in the development of a number of others which are currently being investigated. The Up-
ward Bound Program is under the cognizance of the Faculty Committee on Community Affairs and is supervised by Dr. Menand through the Education Research Center. A faculty group is also planning to operate a work-study transition program this coming summer for a particular group of students planning to enter M.I.T. as freshmen in the fall term who would benefit especially from a transitional academic program, an opportunity to have some technical experience, and an early opportunity to get acquainted with M.I.T. In addition to these established programs, faculty and student groups are exploring the feasibility of a number of additional proposals for assisting black youth at all grade levels to find more adequate educational opportunities.

Teaching and research activities related to the urban scene have flourished in several departments of the Institute for many years, most notably in the Departments of City and Regional Planning, Architecture, Political Science, and Civil Engineering. However, as the scale and complexity of the crisis in urban America has grown, the need and opportunities for creative research, teaching, and direct involvement have similarly multiplied. Increasing awareness of urban needs has been accompanied by a growing faculty and student interest, involving in its sweep departments and schools heretofore only peripherally involved, if at all. A major grant received last year from the Ford Foundation provided means to augment the faculty engaged in urban studies, and to create an interdepartmental Urban Systems Laboratory as a problem-solving center where students and faculty alike could work together on solutions of the intricate problems of the cities. In addition, the grant made possible the establishment of an Urban Fellows Program the purpose of which is to enable young members of the M.I.T. Faculty to spend substantial periods of time working in urban settings, assisting operating managers and planners. The faculty participants take with them the latest ideas and techniques and gain, in return, the type of educational experience that comes only through involvement.

Because of the interschool nature of the expanded urban studies program, we have chosen to coordinate it by means of a newly created committee, the Urban Coordinating Group, whose membership includes the deans of the School of Engineering, the Sloan School of Management and the School of Architecture and Planning, the chairmen of all of the academic departments seriously concerned with urban studies, and a number of key faculty members and administrative officers. The Urban Coordinating Group is chaired by the Provost.

The past year has been one of growing financial stringency for the research centers at M.I.T., as well as for the investigators who receive
their support by means of individual grants. All of the major laboratories have had their budgets for the next year frozen or reduced as a result of the shortage of Federal funds for scientific activities. Most seriously affected has been the Center for Space Research, whose budget has been reduced substantially as a result of the severe cut made by the Congress in the National Aeronautics and Space Administration Sustaining University Program. Major changes in its patterns of operation will be required. Two other laboratories, the Research Laboratory of Electronics and the Laboratory for Nuclear Science, are also forced to make substantial adjustments in their programs as a result of budget shortages. The problem of adjusting the activities in these two laboratories to fit the new budget levels is made more difficult by the fact that they have been operating with essentially constant levels of support for several years despite continuously rising costs. To accommodate the present worsened situation, research activities will have to be curtailed; acquisition of equipment and supplies must, for the most part, be postponed; technical staffs will be reduced; and fewer students will be supported. Under these conditions not only will it be difficult to begin new investigations, but most ongoing activities will be slowed down. M.I.T. will seek alternate support for those research activities whose actual existence is endangered by the cuts in Federal funds, but there can be no hope that the cuts can be offset by monies from private sources. The net result of the present Federal policy is certain to be a decrease in research and training that will leave its scars for many years to come.

During the past year Professor Robert A. Smith resigned as Professor of Physics and Director of the Laboratory for Materials Science and Engineering to become Principal and Vice Chancellor of Heriot-Watt College in Edinburgh, Scotland. He was succeeded by Nicholas J. Grant, Professor of Metallurgy. Institute Professor Jerrold R. Zacharias succeeded Professor Robert I. Hulsizer Jr. as Director of the Education Research Center. Professor Hulsizer will resume his activities in teaching and research. Professor Robert M. Fano retired as Director of Project MAC in order to be able to devote more time to his own research and teaching. Joseph C. R. Licklider, Professor of Electrical Engineering and Associate Director of Project MAC, will assume the leadership of Project MAC in September.

NEROC

M.I.T. faculty and Lincoln Laboratory staff, working together, have continued their active role in the Northeast Radio Observatory Corporation (NEROC), a non-profit organization of 13 universities in New England and New York formed to plan a very large, fully steerable radio-radar
telescope. NEROC has continued a program of engineering studies of telescope design initiated by its predecessor, the Cambridge Radio Observatory Committee (CAMROC). This 2½-year design effort has had the financial support of the National Science Foundation (NSF).

These studies resulted in an important advance in antenna design. They demonstrated the feasibility of low-cost construction for very large (440-foot diameter), fully steerable antennas of sufficiently high precision to operate at short wavelengths (as low as 5 cm). For a microwave antenna, a diameter of 440 feet provides a collecting area more than four times that of any that now exists. The antenna itself would be sheltered from wind, snow, and temperature changes by the protective cover of an electromagnetically transparent space-frame radome. In this controlled environment, the parabolic surface can be maintained to the precision required because deflections which occur when the telescope is rotated are systematic and predictable. The cost can be low because the protected environment permits the use of a very lightweight reflector and a simplified base and control system. The proposed reflector, with a surface of 160,000 square feet (about four acres) will maintain its parabolic shape with a tolerance of 0.1 inches, and the antenna can be pointed with an accuracy of 0.005 degrees. The protective radome will stand 560 feet above the ground — high enough to enclose the Washington Monument.

Some remaining critical alternatives are being explored this year. These include the best distribution of structural materials in the reflector and the best radome configuration to achieve minimum aperture blockage with maximum strength. An NSF panel, which reviewed requests for major radio astronomy facilities, asked NEROC to compare fully steerable paraboloids with Arecibo-type fixed spherical antennas that attain limited steerability through a moveable feed. The resulting NEROC study recognized that spherical antennas can be constructed in the very largest sizes for less cost but are limited to operation at the longer wavelengths and to narrow scan angles. NEROC continued to recommend the steerable paraboloid as the most satisfactory way to fill the need for a microwave telescope with full sky coverage.

The cost of the complete facility planned by NEROC is about $30 million, and a request for capital funds to complete the design and begin construction is awaiting action by the National Science Foundation.

In the meantime, radio and radar astronomers at M.I.T. and the other NEROC institutions have continued to make important contributions to these rapidly advancing fields. Of particular note this year are the fourth test of the general theory of relativity; the first radar detection
of an asteroid, Icarus, as it made its close approach to the earth on June 14, 1968; the measurement of the 3° Kelvin radiation of the primordial universe; the discovery in interstellar space of helium, carbon, and an isotope of oxygen; and the discovery of a new pulsar, one of the newest mysteries in space.

**INTERDEPARTMENTAL BIOMEDICAL ACTIVITIES**

The broad interest of the M.I.T. Faculty in interdisciplinary biomedical and health-related research has been increasingly evident in recent years, and the Committee on Engineering and Living Systems has continued to play a vital role as a coordinating and communications medium for the many diverse forms and directions this interest has taken.

Cooperation between Harvard and M.I.T., latent and under discussion for several years, and formally launched last year with the formation of the Harvard-M.I.T. Joint Committee on Engineering and Living Systems (J.C.E.L.S.), has continued active through the current year with regular meetings of the Joint Committee and its three ad hoc subcommittees on education, medical care, and research. The deliberations of the Joint Committee have repeatedly pointed to the desirability of initiating a jointly sponsored program for research and development in engineering and living systems. Almost coincidentally, the National Institutes of Health (NIH), through the National Academy of Engineering, expressed their interest in the interface between science, engineering, mathematics, and medicine, with a view to creating a program which would not be confined within a university framework, but which would enlist the cooperation of community and industrial elements. Study contracts were awarded to several institutions, including a joint award to Harvard and M.I.T., to consider how the complementary resources of both might best be applied to an action program for improved medical care. A five-man steering committee, under the aegis of the J.C.E.L.S., organized 15 task groups to explore and to propose specific joint activities in their areas of interest. The task groups comprised: artificial organs, bioengineering curricula, biological control systems, diagnostic instrumentation, diagnostic processing, image processing and visualization techniques, medical care microsystems, neurophysiology, organ and cell cultures, physiological monitoring, regionalization of health systems (or macro-systems), sensory aids, skeletal prostheses, continuing education, and subcellular engineering. Group chairmen will submit their reports to the steering committee during the summer in time for the latter, working with the J.C.E.L.S., to submit a proposed program to the National Academy of Engineering in September.
The Education Subcommittee devoted much effort during the year to consideration of a joint M.I.T.-Harvard curriculum leading to an S.B. in an existing academic department from M.I.T. or Harvard, and an M.D. from Harvard Medical School. Tentative proposals were presented to the Curriculum Committee of the Harvard Medical School and to the M.I.T. Committee on Educational Policy.

Since there will be many different career patterns in these joint fields, a joint curriculum is not viewed as a rigid framework but rather as a program which can be varied to fit individual needs. The education of engineers and physical scientists who intend to pursue careers in health or life science-related fields, as well as the postdoctoral training of physicians who wish to expand their understanding of physical science or engineering-related fields, is under active separate consideration by the Subcommittee.

The Subcommittee on Medical Care has recommended that Cambridge be a focus of activity for programs applying management theory and engineering knowledge towards the objective of providing better medical care for the residents of that city.

The Research Subcommittee has explored existing joint activities and is presently summarizing a total of more than one hundred medical and biological projects in which there is ongoing collaboration with engineering groups. In addition, the Subcommittee is actively examining the possibilities of major collaborative research and development programs.

In conclusion, it is gratifying to note that this writing marks the close of the second year of support for interdepartmental biomedical activities at M.I.T. under the NIH Biomedical Sciences Support Program, with a third-year grant presently beginning. With the authority it provides for institutional allocation of funds, this grant has been invaluable in supporting projects for which no other timely support was available or obtainable, and it has greatly strengthened health-related activities at M.I.T.

JEROME B. WIESNER

CENTER FOR MATERIALS SCIENCE AND ENGINEERING
An entity since 1961, when it was funded in major part by the Advanced Research Projects Agency (ARPA), C.M.S.E. took tangible form three years ago in its new quarters in the Vannevar Bush Building. In this three-year period C.M.S.E. has attempted to establish identifiable external form and meaning as well as the necessary internal organs for effec-
tive and efficient life and activity. A number of concepts and innovations in terms of research groupings, central laboratories, equipment procurement, management, and administration have been tried, with varying degrees of success.

The initial participation, restricted to the Departments of Electrical Engineering, Metallurgy and Materials Science, and Physics, has been expanded to include participation by the Departments of Civil Engineering, Chemistry, Chemical Engineering, and Mechanical Engineering. It is expected that a still broader interdisciplinary atmosphere will prevail in subsequent years.

Presently C.M.S.E. houses a total staff of nearly 400. Among the group, we find approximately 53 professors (all classes), 20 other academic staff, 25 D.S.R. postdoctoral staff, and 180 graduate students.

Funding provided by ARPA Contract SD-90 provides for numerous integrated research programs; these funds are supplemented by other smaller, individual contracts, grants and fellowships acquired by individual professors, to round out a fairly broad program in materials research and development.

One of the most important accomplishments made possible by the ARPA contract is the establishment of a series of central laboratories and service centers. In the traditional sense, a professor, his group of students, plus other professionals seek research support in areas of interest. The small, individual contracts seldom provide for large expenditures for equipment and instrumentation, nor do they provide funds for operating such units, often requiring skilled technicians or staff members. The ARPA contract specifically provides funding both for the equipment and its operation, for the good not only of C.M.S.E. but of all materials-oriented groups within the Institute. The current central facilities are the following:

General service facilities:
- Central Analytical Laboratory
- Central Machine Shop
- Electronics Construction and Instrument Service Facility
- Central Computation Facility
- Materials Center Library and Reading Room
- Central Administrative Office

Specialized research facilities:
- Microscopy and Metallography Facility
- X-ray and Electron Optics Facility
- X-ray and Electron Diffraction Facility
- Gas Analyzer Mass Spectrometer Facility
Materials preparation and processing facilities:
  Insulating and Optical Crystal Growth Facility
  Semiconductor Crystal Growth Facility
  Metal Crystal Growth Facility
  Metal Crystal Preparation Facility
  Ceramic Materials Preparation Facility
  Materials Technical Information Services

One of the most recent acquisitions (a very expensive item), a scanning electron microscope capable of providing stereo views, has been over-subscribed from the day of its installation; it is fair to say that a second unit would also be subscribed fully from the day of its installation. The depth of focus, the omission of replication, and the three-dimensional views available make this an outstanding tool for surface and fracture studies.

It is the intent of C.M.S.E. to enlarge existing central facilities as the need dictates, and to modify older or initiate new centers for the good of the entire materials community.

C.M.S.E. was planned originally as a larger facility, capable of drawing together more groupings of common or related interest and talent. There remain numerous scientific and engineering groupings in the Institute which could benefit in a major way from an interdisciplinary approach, especially through the availability of modern, high-speed, precision equipment, and instrumentation and service groups which cannot be justified or attained for individual effort. It is the intent of C.M.S.E. to stimulate such groupings and associations and to seek funding to implement their needs and aims.

C.M.S.E., from its inception until June 1, had one Director, Professor Robert A. Smith, who devoted himself unselfishly and with enthusiasm to achieve and exceed the goals set up for such a Center. He has returned to Scotland to become the Principal and Vice-Chancellor of Heriot-Watt University in Edinburgh. Professor Smith deserves high praise and our gratitude for the excellence of the Center and for having molded a smooth and effective operation. This was no small task.

RESEARCH ACTIVITIES

In the limited space available it is impossible to do justice either to the individual items or groups of items of research or to the impact such research will have on scientific knowledge or materials and device developments. There is a considerable effort within C.M.S.E. to stimulate new research ideas; often the results of such seeding may be a number of years away. The following is at best a brief and sketchy recapitulation.
Professor George B. Benedek’s group has been studying the spectrum of laser light scattered from thermal fluctuations in liquids and solids. This group has made advances in three general areas in the past year. First, they have succeeded in detecting the natural width of the Brillouin components in the light scattered from a single crystal of ammonium chloride. This has permitted, for the first time, a measurement of the lifetime of a microwave (~20 GHz) sound wave in a solid at room temperature. This experiment opens the way to detailed studies of the mechanisms for the damping of thermally excited sound waves in solids, and it will have important applications in understanding related transport properties such as the thermal conductivity of insulating and semiconducting crystals. Second, by using the ultrahigh resolution techniques of “self beating spectroscopy,” they have studied in great detail the spectrum of light scattered from a pure fluid, SF\textsubscript{6}, along a series of paths in the immediate vicinity of the critical point. Among other results, their measurements show for the first time the existence of a “spinodal line” in the phase plane of the fluid; that is, the equilibrium properties of the fluid appear to diverge not at a single temperature, the critical temperature, but rather along a line of discontinuities called the spinodal line. This line is familiar to metallurgists working with alloy phases and with glasses. Professor Benedek’s results demonstrate that such a line exists in a single component fluid. There are clear indications that two component mixtures also will exhibit a spinodal line. Finally “self-beating spectroscopy” has been used to detect the spectrum of light scattered from solutions of biological macromolecules. The spectral width of the scattered light provides a measurement of the diffusion constant of these macromolecules. In this way Professor Benedek’s group has been able to detect changes in the size of biological macromolecules as the chemical composition of its environment changes. For example, they have detected a marked change in the size of the protein, lysozyme, as it undergoes denaturation by guanadinium chloride. Also, by combining their diffusion constant measurements with a determination of the sedimentation velocity of molecules in an ultracentrifuge they have been able to establish a very accurate value (49.6 ± 1 \times 10^6 grams per molecule) for the molecular weight of T\textsubscript{7} bacteriophage. It appears that this technique will be the major source of accurate information on the mass of molecules whose weights exceed ~50 \times 10^6 grams per molecule.

Professor James D. Litster’s group is studying the Faraday rotation of light in the ferromagnet CrBr\textsubscript{3} near its critical temperature of 32.5°C. This enables them to make precise measurements of the magnetization as a function of applied field and the divergence of the susceptibility in...
the critical region. This work also has potential applications as a means of modulating laser beams. They plan to study the velocity and attenuation of microwave phonons as a function of temperature near the critical point of antiferromagnetic RbMnF$_3$ and ferrimagnetic RbNiF$_3$.

The group is studying light scattered by thermally excited sound waves in crystals in the region of the melting point; from the Brillouin spectrum one can measure the velocity and attenuation of microwave phonons in both the solid and liquid phase. Of particular interest is the behavior of the transverse phonons as the solid approaches the melting point.

Professor Thomas J. Greytak's group is concerned with the velocity and attenuation of thermal sound waves at about 700 MHz below and in the vicinity of T$_\lambda$. Measurements are planned of the complex spectra corresponding to first sound, second sound, and concentration fluctuations in the superfluid phase of the two-component He$_3$-He$_4$ mixture.

Professor Marlan O. Scully plans to extend the quantum theory of an optical maser in several ways. Programs on coherence in atomic processes, the acoustoelectric effect, superfluid physics, and transport processes in liquid HeII are under way.

The principal activity of Professor George F. Koster and his colleagues was in the field of energy band calculations in solids. In particular, a self-consistent Hartree-Fock-Slater band calculation was carried out on lithium. Further, a relativistic energy band calculation was performed for the two tin structures.

Professor Carl W. Garland of the Department of Chemistry and his research students have completed several ultrasonic investigations of order-disorder phenomena during the past year. Velocity measurements on KH$_2$PO$_4$ in its paraelectric phase near the Curie point (T$_c$ = 121.8 K) show that the shear constant c$_{66}$ goes to zero at T$_c$ according to an elastic Curie-Weiss law. In addition, the KDP attenuation data are consistent with a cooperative relaxation time of the form A/(T-T$_c$), as predicted by Landau. An investigation of NH$_3$Br as a function of pressure at low temperatures has revealed a new ordered phase above 2 kbar at $\sim$200 K. Thus, there are two lambda lines marking cooperative transitions to the disordered phase and a new triple point. Velocity measurements in the new phase and in the transition regions have provided a clarification of the complex ordering processes in NH$_3$Br. In the simpler case of NH$_3$Cl, with its single lambda transition between a cubic ordered and disordered phase, attenuation measurements have been completed over a broad range of pressures. These data provide, for the first time, information on the variation of the cooperative relaxation time $\tau$ as a function of volume as well as temperature. It is found that the character of the variation in $\tau$
changes as one moves up along the lambda line, in contradiction to the simple expectations of a corresponding states theory.

Professor Robert J. Silbey, also of the Department of Chemistry, is undertaking studies of the excited states of molecular crystals, the interactions of radiation with these crystals, and, most important, the interaction of the excited electronic states with lattice vibrations and with other electronic states.

Professors Frederick J. McGarry and Robert B. Williamson of the Department of Civil Engineering have pursued three research tasks dealing with cementitious materials. These are: cure time-shrinkage-weight loss studies in hydrating cement, relationships between microstructure and mechanical properties of cement-sludge systems, and morphological studies of hydrated cement. Electron microscopy has been used extensively to study the unstable growth of very thin (100 Å) sheet crystals which are the principal hydration product; the instability appears to be due to constitutional supersaturation, which results in crystal multiplication without nucleation.

The Department of Mechanical Engineering is represented in the Center-supported research by Professors Ali S. Argon and Frank A. McClintock, who are investigating the mechanisms of fatigue damage in semibrittle materials at elevated temperatures. In this instance the use of the Electron Optics Central Laboratory is an example of the interplay of several disciplines toward a common purpose. Ready availability of electron microscopy and scanning electron microscopy will be an important factor in the progress of such studies. Professor Charles A. Berg is initiating a program on the physics and mechanics of deformation and fracture in heterogeneous materials.

The Department of Electrical Engineering contributes an important research grouping which concerns itself with insulators, semiconductors, magnetic materials, crystal physics, and a variety of sophisticated devices. In addition, several of the faculty members are responsible for a crystal preparation central facility and a similar one for growth of insulating crystals.

Professor Alexander Smakula and co-workers are studying the general properties of Raman scattering in mixed perovskite ferroelectric crystals at low temperatures, and luminescence, with particular attention to materials parameters affecting the operation of optically pumped lasers.

Professors Richard B. Adler, Floyd O. Arntz, and Daniel L. Smythe are studying the optically pumped absorption in II-VI compounds; cooperative diffusion effects ("collector dip"); the multiphoton Franz-Keldysh effect, and related non-linear optical phenomena; and the funda-
mental limitations on the packing density of high-speed sequential integrated circuits.

Professor Robert H. Rediker is studying the electrical and electro-optical properties of heterojunctions; the heterojunctions are being fabricated by interface alloying. Professor David J. Epstein is examining the effect of optical excitation on magnetic ordering, anisotropy, and loss in doped ferrimagnetic garnets. Also of interest are the conductivity and dielectric properties in ferrimagnetic garnets.

Professor Frederic R. Morgenthaler and his students have been concerned primarily with microwave magnon-phonon-photon interactions. Interest in this new field of what may be called "microwave magneto-ultrasonics" is warranted because of the fundamental information concerning spin-elastic wave interactions which can be obtained from magnetic and/or ultrasonic spectroscopy and because these interactions make possible novel microwave devices such as magnetoelastic wave parametric amplifiers, tunable delay lines, and pulse compression filters. A highlight of this study is the observation that the frequency of a magnetoelastic wave propagating in a ferrimagnet can be altered by a suitable time variation of the bias magnetic field, and the character of the wave converted from magnon-like to phonon-like (or vice versa) by suitable time and/or space variation of the bias field.

Following an earlier determination of the energy band structure of PbTe, PbSe, and PbS in the materials theory group of Professor George W. Pratt, the group has gone on to investigate the wave functions and energies of impurity states due to a Pb vacancy or negative component vacancy. This has been done using a $k\cdot p$ representation of the band structure not only near a point of high symmetry but throughout the entire Brillouin zone. The band structure of Bi has been calculated using the APW method, and the magneto-optical properties have been determined experimentally using the facilities of the Francis Bitter National Magnet Laboratory. An experimental program on PbSe lasers has successfully achieved lasing in PbSe material grown by Professor Harry C. Gatos, by optical pumping with a GaAs laser. The lasing properties of PbSe under external uniaxial stress are being studied. The theory of the metal-insulator transition proposed by Mott and observed in several transition metal salts has been investigated using a newly developed statistical mechanical approach. This theory has been applied to the theory of boiling, predicting the boiling points of the alkali metals to within 10 per cent.

Finally, Professor Leonard W. Gruenberg and students are continuing studies of high field superconductors. Of interest are the oscillatory prop-
erties of Type II superconductors, which are analogous to the de Haas-van Alphen effect in normal metals. In addition, they are studying the properties of very high field materials for which the Pauli paramagnetism of the normal metal plays an important role in limiting the upper critical field; of interest are the effects of magnetic impurities on such superconductors.

The metallurgy and materials portion of the Center is a large active research group covering a very broad spectrum of materials, their structure and properties. Professors Benjamin L. Averbach and David J. Sellmyer are attempting to place the theories of alloy formation on a sounder foundation. Fermi surfaces are being measured in both dilute solid solution and highly ordered alloys. Professor Sellmyer is investigating the occurrence of localized and cooperative magnetic effects in dilute and concentrated alloys of magnetic metals in normal metals. Professor Simon C. Moss and students are concentrating on scanning electron diffraction and energy loss studies in thin films; amorphous films will continue to be studied. This group of professors and students represents a close link with the solid-state physics research group.

The electronic materials group under Professors Gatos and August F. Witt has focused its efforts on several aspects of the preparation and characterization of electronic materials (semiconductors and superconductors). The techniques developed in the group for studying the instantaneous rates of solidification and growth interface morphology have advanced significantly the understanding of the mechanism of incorporation of defects and trace impurities in semiconductor single crystals. A quantitative model was developed which was experimentally verified and allowed, for the first time, the preparation of completely homogeneous semiconductor single crystals. An interesting consequence of the newly developed crystal growth concepts was the successful preparation, in single crystal form, of alloyed semiconductors (InSb-GaSb) across the phase diagram. Further, a combination of chemical and mechanical processes has led to the preparation of heretofore unavailable atomically flat CdS surfaces. Compensation of germanium single crystals with gamma radiation (Co^{60} γ-rays) has been studied in connection with the detection of high-energy radiation. Detection action has been achieved employing a Cs^{137} radiation source. The study of the superconductor transition temperature and the critical magnetic field has been completed for about 40 ternary alloys in the Ti-Nb-V system. These results show that a quantitative relationship exists between the four parameters: superconductor transition temperature, critical magnetic field, valence electrons, and lattice parameters.
Professor Robert M. Rose and students report confirmation of strong, long-range proximity effects in Nb-Cu composite materials. Sensitive magnetic measurements at low temperatures show that superconductivity is present in appreciable portions of the copper in these composites; copper is not normally a superconductor. The unusual strength and range of these effects is explained by the metallurgical techniques involved in fabrication of the composite, which generate cleaner interfaces and more optimal geometrics than have been realized otherwise.

Professor Donald R. Uhlmann's group is interested in the relationship between the structure and properties of polymeric materials; variables include crystallization at one atmosphere, and at very high pressures. Professor John F. Breedis is studying deformation and strengthening mechanisms; his group is concerned with deformation of hcp alloys, fatigue of titanium alloys, strengthening through spinodal decomposition, and deformation of fcc metals at very high strains. Professor Kenneth C. Russell and students are studying electron irradiation damage of iron and dilute Fe-C alloys at 4.2°K. Professor Keith H. Johnson is investigating the electronic structure of several intermetallic compounds having the cesium chloride, fluorite, and nickel arsenide crystal structures. Professor Roy Kaplow's group is studying Mössbauer spectroscopy of quenched and splat-cooled iron alloys; electron momentum distributions in Be and Be-Cu through inelastic X-ray scattering; optical spectroscopy in metallic alloys; near neighbor strains in cold worked Ni by means of radial distribution functions from X-ray diffractions; and the structure of liquid metals by X-ray and neutron diffraction.

Over-all, this represents an important fraction of the research effort and output of C.M.S.E. It is expected that important changes will take place from time to time in emphasis, scope, and degree of interdisciplinary interplay. Newly conceived research efforts will continue to be encouraged by means of seed-money provided from ARPA funds. It is hoped in particular that additional central facilities will be developed as new demands arise for specific types of instruments, equipment and measurements. While the Center is no longer a new venture, it is still a young one, and shifts in emphasis, in personnel, and in facilities should be expected as a more effective operational structure develops. The extent of interdisciplinary operation and stimulus is still small, but important strides have been made in improving such interplay; more, undoubtedly, can be accomplished with further exposure and through the experiences gained in these last three years.

NICHOLAS J. GRANT
The Center for Space Research, formally established by M.I.T. in April, 1963, with the support of institutional research and facility grants from the National Aeronautics and Space Administration (NASA), has been engaged in a vigorous program of space research in both the traditional academic disciplines and some interdisciplinary areas of special relevance to the national space program. While the larger activities center on research in astrophysics, and engineering studies in space communications and interplanetary navigation, equally important studies are under way in management and social science, dealing with the social and economic effects of this highly technological program.

The new Space Center building became available for occupancy during the past year, and improved considerably the opportunity for useful interaction between researchers in the diverse disciplines involved in the Center's broad program.

The total program of research in the Center is no longer growing at the expected rate, due to the severe budget limitations and stretch-outs occasioned by the reduced Federal budget for fiscal year 1968 and that projected for fiscal year 1969. Some continued growth has been experienced in new payload projects supported by established flight programs within NASA. However, the general research funds of the Center, provided under NASA Sustaining University Grant NsG-496, have been markedly reduced. The consequence has been a regrettable curtailment of the general research program of the Center at a time when a consolidation and strengthening of critical-sized efforts was in progress and when support for new and promising studies was in greater need than ever.

The new building, occupied in January, 1968, and providing approximately 100,000 gross square feet of air-conditioned space, was dedicated in impressive ceremonies on April 25, 1968. A morning panel discussion on space research at M.I.T. was followed by a dedication luncheon and an address by NASA Administrator James E. Webb. An informal reception and open house were conducted in the Space Center building following the dedication. The large attendance by representatives of government, industry and the academic community was indeed gratifying.

Present occupancy in the Center for Space Research includes the following groups, going in order from the sixth floor down to the basement: the Cosmic Ray Laboratory under the direction of Professor Bruno B. Rossi, Institute Professor; elements of the Laboratory for Space Experiments under the direction of Professor Herbert S. Bridge of the
Department of Physics; the Space Science Reading Room; the Fluid Dynamics Laboratory under the direction of Professor Leon Trilling of the Department of Aeronautics and Astronautics; elements of the Electronics Systems Laboratory under the direction of Professor J. Francis Reintjes of the Department of Electrical Engineering; the Space Propulsion Laboratory and plasma physics research under the direction of Professors Jack L. Kerrebrock and James E. McCune, respectively, both of the Department of Aeronautics and Astronautics; elements of the Experimental Astronomy Laboratory under the direction of Professor Winston R. Markey of the Department of Aeronautics and Astronautics; nutrition and life science research under the direction of Professor Richard J. Wurtman of the Department of Nutrition and Food Science; Space Center administration and classrooms; the Man-Vehicle Control Laboratory under the direction of Professors Yao T. Li and Laurence R. Young of the Department of Aeronautics and Astronautics; additional classrooms; and finally, elements of the Aeroelastic and Structures Research Laboratory under the direction of Professor Emmett A. Witmer of the Department of Aeronautics and Astronautics. Two groups scheduled to take up occupancy in the near future include a research group in geophysics and a research group in the social sciences.

The over-all sponsored research budget of the Center for fiscal year 1969 is projected at about $4 to $5 million. When fully occupied, the Center building will include approximately 40 faculty, 60 visiting and research staff, 100 students and 70 support personnel, for a total of about 270. Additional personnel connected with sponsored research of the Center but housed elsewhere number approximately 80 persons.

Technical publications and theses have continued to show a substantial growth in numbers along with the growth in the Center's programs. Approximately 195 journal articles and research reports have been published during the year. Twenty-nine graduate theses were completed during the same period.

SUMMER INSTITUTE ON DYNAMICAL ASTRONOMY

The Center for Space Research was host to a most successful Summer Institute, June 17 through July 12, 1968, on Dynamical Astronomy, which was conducted by the Experimental Astronomy Laboratory under the direction of Professor Markey, Professor Victor Szebehely of Yale University, and Dr. Robert G. Stern of the Experimental Astronomy Laboratory at M.I.T. The Summer Institute was jointly sponsored by the National Science Foundation and the National Aeronautics and Space Administration (NASA) and was attended by approximately 125 partici-
pents drawn from universities, industry, and government. The Electronics Research Center of NASA and the Smithsonian Astrophysical Observatory joined with M.I.T. in seeking support for and in arranging the technical program. A repeat program in Celestial Mechanics and Astrodynamics has been proposed for 1969.

SPACE EXPERIMENTS

The Center’s Laboratory for Space Experiments was formed in 1964 for the purpose of providing engineering design support for a variety of space payloads, the scientific objectives of which were the responsibility of M.I.T. faculty as principal investigators. The growth of this Laboratory has been particularly significant, and present program research funding for its activities has reached a level of about $1,600,000 per year. Its personnel count is now about 80, including 20 research staff. A number of faculty members are associated with its various project activities. With the expansion of its responsibilities, the laboratory has recently been reorganized and placed under the direction of Professor Bridge with Richard H. Baker serving as Associate Head. Professor John V. Harrington, as Director of the Center, continues his association with the Laboratory as principal investigator of its Sunblazer project. The objective of Sunblazer is to measure the electron density profile with good accuracy over the 5 to 100 solar radii distance from the sun, thus resolving the considerable ambiguity now present in radio star occultation measurements. A secondary objective is the measurement of scintillations in angle and time of arrival of coherent transmissions as occultation progresses, from which the fluctuations in electron density and the scale of turbulence in the inner corona can be determined. Provisions also exist to carry a limited number of on-board sensors to make particle and field measurements in the 0.5 to 1.0 A.U. region of interplanetary space. These include a Geiger counter experiment to count energetic particle fluxes in the 0.5 to 0.6 A.U. region, a study of the cosmic ray gradients in the 0.5 to 1.0 A.U. region, a study of X-ray sky background in the antisolar direction, a study of plasma densities and velocities in the 0.5 to 1.0 A.U. region, an experiment using a flux gate magnetometer to measure magnetic field strength at 0.5 A.U., and a fourth test of general relativity requiring coherent X-band transmissions between the Sunblazer spacecraft and the Haystack radio telescope.

Clearly, this sort of ambitious program would extend over several launches and many years of investigation, and the plan is now in the initial stages of implementation by NASA.

The spacecraft to carry these experiments into space has been de-
signed by the Laboratory and prototype models are already completed. The spacecraft weight is approximately 28 pounds.

Considerable work has been expended both at M.I.T. and by Dr. Jesse James and his staff at the El Campo, Texas, Solar Radar Observatory, in the development and test of pilot models of a phased array antenna system suitable for the reception of Sunblazer signals. Pulse techniques for signal transmissions from the spacecraft are proposed, the reception of which requires a ground-based antenna with a ten per cent bandwidth, a 50 db gain and with dual polarization. Fundamental studies in deep space communications problems with emphasis on the transmission of coherent signals through a dispersive medium have been carried out by Professors Wilbur B. Davenport and Robert D. Yates, both members of the Department of Electrical Engineering, in conjunction with a number of graduate students.

A second important task within the Laboratory involves the design and construction of payloads for sounding rocket experiments to measure weak X-ray signals from extragalactic objects such as Seyfert galaxies and supernova remnants. The measurements center on long wavelength \((10 - 44 \text{ A}^\circ)\) X radiation, which determines the wavelength of interstellar cutoff, the energy spectra of X-ray sources up to energies of 20 keV, and the sizes and positions of X-ray sources with high precision; use of modulation collimator techniques is made where appropriate. Several experiments have been carried out on Aerobee sounding rocket flights, obtaining data which have been subsequently analyzed and published by Professors Hale V. Bradt and Herbert W. Schnopper of the Department of Physics, and their associates at M.I.T. Engineering design construction and test of the payload has been carried out under the supervision of Mr. Robert W. Rasche, D.S.R. staff member of the Laboratory.

A third important area of activity of the Laboratory deals with the engineering design of plasma probes to be carried in NASA's payloads for IMP (Interplanetary Monitoring Platform) scientific satellites. The object is the measurement of the interplanetary plasma and solar wind intensities and velocities in the region of the earth and the moon. A considerable amount of data (which has done much to refine our understanding of the nature and extent of the solar wind and its interaction with the earth, the moon, and some of the near planets) has been collected by these scientific payloads. This research has been carried out and reported upon in publications by Professors Bridge and Alan J. Lazarus of the Department of Physics, and Dr. Joseph H. Binsack and Dr. Ervin F. Lyon of the Center. Additional experiments are planned for IMP-H and IMP-J.
series, for which the mission objectives involve more detailed and accurate measurements of the solar plasma properties and their variation with time, and the interaction with the geomagnetic field. Important data on the energy distributions of electrons and protons will be obtained close to the ecliptic plane in a roughly circular orbit of radius about 35 $R_e$. The detector itself is a Faraday cup with AC modulation potential applied to one of the grids. Engineering design, construction, and test of the instrument payload is being carried out in the Laboratory for Space Experiments under the immediate supervision of Robert J. Butler, D.S.R. staff member.

A fourth major payload design task concerns a "multi-color" X-ray sky survey experiment for NASA's Orbiting Solar Observatory OSO-H. The scientific program is under the over-all direction of Professor George W. Clark of the Department of Physics. The objective of this project is to achieve an all-sky survey of the positions of cosmic X-ray sources and the spectra and time variations in these sources for a wavelength range from $1.5 \, \text{Å}^\circ$ to $9 \, \text{Å}^\circ$ (1 to 15 keV) in two broad bands ($1.5 \, \text{Å}^\circ$ to $4 \, \text{Å}^\circ$ and $3 \, \text{Å}^\circ$ to $9 \, \text{Å}^\circ$) in order to provide a "two-color" survey down to source intensities equal to 0.002 times that of Tau XR-1.

The instrument and electronics for the basic experiment will occupy a sector of the oso wheel. The X-ray detectors will be double Geiger counters with $3.6^\circ$ (full width) honeycomb collimators, $150cm^2$ sensitive areas, and anticoincidence shielding. Precision aspect data will be obtained from a star sensor and a sun sensor fixed to the instrument and aligned with respect to the X-ray collimator. The equipment will weigh 35 pounds and consume 2.5 watts of power.

In addition to the specific projects described above, a number of exploratory and preproposal studies of possible programs of the future are under way in this Laboratory. These studies are providing interesting and important topics for faculty and graduate student investigations, and the response in this respect within the Laboratory has been most gratifying. Both faculty and student participation have been increasing significantly, as has participation by visiting foreign scientists and engineers.

JOHN V. HARRINGTON

COMMITTEE ON INTERNATIONAL AFFAIRS

The Committee on International Affairs was established in the spring of 1966 shortly after the Institute had received a grant of $8,000,000 from the Ford Foundation in support of teaching and research activities in
international affairs. The central purpose of the committee, which is chaired by Professor Max F. Millikan and includes the Provost and the Deans of the several Schools, is to oversee allocation of the Ford grant. The funds are intended to provide seven endowed professorships, five of which have now been assigned to the Departments of Economics, Humanities, and Political Science, and to help support the Institute's international research program over a five-year period. During the past year the Ford funds were used to finance, wholly or partially, various studies being carried out in the Center for International Studies, the School of Engineering's Inter-American Civil Engineering Program, research and training programs in the School of Architecture and Planning on urban and regional problems in the developing countries, and teaching and research in contemporary history within the Department of Humanities. A good start was also made on improving the international social science collection of the Dewey Library.

Beyond the primary function of supervising expenditure of the Ford Foundation's grant, the Committee has also begun to serve as a forum for discussion of the Institute's international activities more generally. The steadily expanding scope and variety of these international interests has made it important that there be a readily available channel for communicating information about existing commitments and exploring proposals that might lead to substantial new international involvements.

MAX F. MILLIKAN

EDUCATION RESEARCH CENTER

The last annual report included the start of several new activities and the beginning of financial difficulties. This year's activities show strength in major accomplishments in new programs, as well as in the well-established ones, and significant success in meeting the financial needs of the Center.

The program with the longest and strongest history has been that of Physics Curriculum Development. Started in 1960 with the inception of the Center, it has produced many demonstrations, experiments, films and preliminary text materials. This year finds the first of 13 introductory physics texts complete and ready for publication in August, 1968, by W. W. Norton & Company, Inc. of New York. The first is on special relativity. Three more on mechanics are in final draft. One on quantum mechanics and one on electricity and magnetism are in preliminary form. All of these materials have been in trial use at M.I.T. and many other universities for several years.
An experiment in self-study in physics, using the quantum mechanics text and audio tape materials, filmed demonstrations and study guides, has been prepared for the fall term of 1968 with M.I.T. students.

The National Science Foundation (NSF) has extended its grant in support of this physics program for another two years at $330,000 per year.

Work in the laboratory has been directed chiefly at the production of prototypes of a variety of simple "corridor experiments" in dynamics, oscillatory motion, and electromagnetism. An experiment on the Fizeau "ether-drag" effect, using a ring laser, was also developed for use as a filmed demonstration.

During 1965-1967, a conversational tutoring system, called ELIZA, was devised that operates on the M.I.T. time-sharing system. The computer and student "converse" by way of a standard typewriter terminal. The system is designed to analyze with some sophistication the things that the student types and to respond appropriately using both textual and computational processing. It is possible to carry on a connected and coherent conversation including digressions. During the summer of 1967 a tutorial program was written that teaches a one-week topic in special relativity. Students who tried the program found it useful and only mildly awkward. The programs were improved significantly.

The ELIZA program has been discontinued. Aside from inadequate funds, the reasons for this discontinuance are:

1. Too much programming time is required to set up a tutorial in a given topic.
2. The ELIZA system must communicate in a restricted context at any point in the conversation. It is virtually necessary to have the machine ask questions of the student in order to limit the context of his reply. Such domination of the conversation by the machine runs counter to our goal of letting the student use the machine as a slave in mastering a given subject.

The experience gained from the ELIZA program has been invaluable in designing a subject in computer programming in which all the instruction and exercises take place at a computer console. This latter work is continuing under the sponsorship of the Department of Electrical Engineering, which offers the subject for credit. A National Science Foundation grant was awarded to the Education Research Center (E.R.C.) to analyze, evaluate, and improve this subject in computer-instructed computer programming.

Another activity in the computer field has been the production of computer-generated films and illustrations. The work started in 1966
with a computer provided by NSF to experiment with the production of films to show the structure of protein molecules. This program has been expanded and now includes films in physics, chemistry, and electrical engineering as well as the original molecular biology topics.

For the biology program the computer accepts tridimensional coordinates of "stick models" of molecules as basic input. The coordinates are fed directly into the computer from the keyboard, read from disk files, or generated by a coordinate-generator program.

By using a 16mm camera under computer control to photograph the face of the cathode ray tube display console of the computer, linked to an IBM 7094, three films illustrating fundamental biochemical reaction mechanisms have been produced:

1. A 15-minute movie on the Biosynthesis of Steroids, showing the polymerization of derivatives of isoprene into squalene and polycyclisation of squalene into Lanosterol. The emphasis is on stereochemical changes and intra-molecular rearrangements.

2. A 10-minute movie on Pyridoxal-Phosphate Catalyzed Reactions, showing, as an example, the racemization, decarboxylation, transamination, and dehydration of the amino-acid serine.

3. A 10-minute movie on Peptide Bond Formation and Protein Structure.

To our knowledge, these films represent the first attempt to use computer-animated movies to visualize biochemical reaction mechanisms involving three-dimensional changes.

On the basis of the work in biology and preliminary films in physics, NSF awarded the Center a grant to expand the computer facilities and to produce 30 films. The present status of this production is as follows:

1. A set of six computer-generated films in quantum mechanics was completed and made commercially available.

2. A set of five short films in physical chemistry has been produced and will be released shortly by the Advisory Council on College Chemistry.

3. Development of teaching films in electrodynamics, relativity, mathematics, and biochemistry has begun.

4. Still photographs from computer-generated motion pictures produced at E.R.C. have appeared as illustrations in a large number of new physics texts.

5. Several articles describing particular films have appeared in the American Journal of Physics.

With the support of a grant from Dr. Edwin Land, a number of films that demonstrate modern techniques in neurophysiology are being developed for the new project laboratory in biology at M.I.T. The films cover
method of dissections and the use of instruments necessary for this subject. We have used some of these films as lecture material in the spring term of 1968. We anticipate having these materials in a film-loop format for future use.

The long-term study of the adaptation of students to the demands and goals of M.I.T. has continued. The original four-year study of the class of 1965 was brought to completion with several reports to the Faculty. A book on the study is in final draft. This study encouraged the staff to probe more directly into classroom and laboratory situations both to find out something about how they function educationally and to find out how the students view them as educational experiences. A substantial facet of this study has been to learn something about the various learning styles of the students. These studies extend our probing into the social-adaptive aspects of education. An initial study by Dr. Benson R. Snyder established that observation of and direct participation by the observer in classes at M.I.T. was an informative research method. One such investigation was in a physics recitation section. With the cooperation of the instructor, Dr. Snyder evaluated both innovative teaching techniques and the ways in which the formal and informal curriculum could be seen to interact within the classroom.

In a second study, Dr. Malcolm R. Parlett observed another classroom situation without participating in discussion. His interaction with the students was limited to contacts outside the classroom, partially structured interviews, and a variety of questionnaires.

It was shown in both studies that close attention to other aspects of individual students' lives is crucial if the investigator is to understand the events and atmosphere of the class and the role of particular members within it.

Other work in progress by Dr. Merton J. Kahne and Dr. Parlett involves studying two separate classes within a single department. These studies focus on the social structure of the subject as it influences, and is influenced by the behavior and psychology of its participants. One approach attempts to combine organization theory, sociological theory, and psychoanalytic propositions to make a formal statement about an educational environment. The other approach relates classroom events to particular psychological attitudes of the participants, examining "risk taking" by undergraduate students. It is hoped to distinguish those students who need external control and authoritative guidance from those students who seem naturally adapted to working in a freer, open-ended, and unsupervised study environment.

The group also participated in the supervision of five theses, four
graduate and one undergraduate, on topics related to general interests of the Center.

In the past, support for the study of the students' adaptive processes has been provided by the W. T. Grant Foundation, the Victoria Fund, the Bing Foundation and the National Institutes of Health. The National Institute of Mental Health has recently awarded funds for one year for the continuance of this program with recommended support for three years.

At the end of the current academic year the Director, Robert I. Hulsizer, asked to be relieved of his responsibilities in order to devote more time to teaching physics and to his research activities in elementary particle physics. Professor Jerrold R. Zacharias has agreed to assume the directorship starting in June, 1968.

ROBERT I. HULSIZER

LABORATORY FOR NUCLEAR SCIENCE

Including work in cosmic rays, high-energy, low-energy and theoretical nuclear physics, the Laboratory's physics research program last year involved the support of 62 physics faculty members, 124 doctoral students and approximately 120 undergraduates. In addition, the Laboratory continued its support of research and instrumentation programs in nuclear inorganic and physical chemistry, "hot atom" chemistry, and nuclear organic chemistry. Summaries are given below of Laboratory for Nuclear Science (L.N.S.) physics research for the year. The work of the chemistry groups is, as usual, presented in the report of the Department of Chemistry.

Other Laboratory personnel involved in L.N.S. physics programs totaled approximately 260 people, including doctoral research personnel, technical and administrative support personnel. Expenditures for research operations in physics during the year totaled approximately $6,160,000, including funds for the purchase of major research equipment, one of which was the IBM 360/65 computer acquired to replace the Laboratory's IBM 7044 machine.

Beyond the new computer acquisition, items of special note were: the commitment for construction, and the good progress, of all major elements of the Laboratory's new 400 MeV linear accelerator (building, accelerator transmitter and waveguide systems); the completion, occupancy and dedication of the Department of Physics' excellent quarters for the Center for Theoretical Physics, which will henceforth house, among others, departmental and L.N.S. staff engaged in theoretical
nuclear physics; the successful application to physics data of the high-speed bubble chamber data analysis device, PEPR, that has been under development in L.N.S. by Professor Irwin A. Pless’s group over the past several years; and the submission to the Atomic Energy Commission (AEC) and the National Science Foundation (NSF) for the implementation of a Tandem Van de Graaff Laboratory (HILAB), under M.I.T. sponsorship, that would serve as a nuclear physics research center for a number of interested laboratories and universities throughout the country.

The Laboratory's research, as before, covered a broad range of work on campus in theory and in experimentation with the Laboratory's cyclotron and Van de Graaff accelerator. Off campus, programs have been continued at the Cambridge Electron Accelerator (C.E.A.), the Brookhaven and Argonne National Laboratories (BNL and ANL), and the Stanford Linear Electron Accelerator (S.L.A.C.). A significant series of experiments by M.I.T. staff was begun also last year at the Deutsches Elektronen-Synchrotron (DESY) at Hamburg, Germany. This work is expected to continue through the next few years.

Of great importance this year was the hardening of the nation's position with respect to basic research budgets. The immediate impact on the Laboratory has been severe and has necessitated substantial readjustment of virtually every Laboratory project, as well as the making of plans for coming years that hopefully will be in keeping with the financial limitations that will clearly have to be faced. Among other things it has been decided to terminate early during the summer of 1968 the Laboratory's nuclear physics program at the cyclotron; all other research programs have been reduced and slowed, and many have been stopped. In particular, the seeding of new research efforts has been reduced greatly. The last is of special concern, since forward planning of this kind is essential to develop the ground for the research of coming students, and the quality and predictability of such programs is obviously a critical factor in drawing bright young men to these difficult fields. An oblique but related situation, indicative of the problem on a national scale, has been the effect of reduced budgets at Argonne National Laboratory on the proposed program there with the erstwhile M.I.T. bubble chamber. This equipment, which has been demonstrated to be an unusually effective instrument, cannot be supported as was planned originally. The research program with it is being dropped and the chamber will be put in indefinite stand-by condition.

Of note also is the move, as planned, to administer and house some of the specialized National Aeronautics and Space Administration (NASA)-
supported space research activities of the L.N.S. Cosmic Ray group at the new Space Research Center that was completed and put into use early in 1968.

STATUS OF NEW FACILITIES

TANDEM VAN DE GRAAFF

An important extension of particle-induced reaction studies involves the use of proton beams of precisely controlled energies in excess of 20 MeV and heavy ion beams of considerably greater energy. To this end, the Laboratory made proposals during 1966 and 1967 to the Atomic Energy Commission for acquisition of a TU Tandem Van de Graaff accelerator. This was not responded to favorably in either year and it is clear that the AEC is not likely to be able to fund such a facility for some time. During the past year, the possibility emerged of acquiring this capability satisfactorily, at least in the interim, by means of a facility that could be used jointly by a number of laboratories and universities throughout the country. A consequence of this has been the proposal by M.I.T. through the Laboratory for Nuclear Science, and on behalf of a consortium of scientists from institutions elsewhere, for the establishment of a heavy ion laboratory (HILAB) in Burlington, Massachusetts. It would be intended to use this facility in general for pertinent reaction studies of all kinds, but initially with emphasis on heavy ion experiments in physics and chemistry. A primary focus of these investigations would be a search for new elements and new isotopes of known elements. The fundamental nuclear structure experiments being carried on by the laboratory’s on-campus groups will meanwhile continue with existing facilities until such time as it becomes possible and desirable to transfer them to HILAB, as and if this becomes appropriately extended, or to such new facilities as may become available at other laboratories (for example BNL) or in L.N.S.

LINEAR ACCELERATOR

As of June 30, 1968, preliminary design on all elements of the construction project has been almost completed. Construction activity on major components is well under way, with the buildings being now about 30 per cent complete. Construction of the transmitter, including its klystrons and switch tubes, and on the accelerating waveguide system, is progressing at a rate that should allow comprehensive prototype tests to be begun as planned during the fall of 1968. It is expected that all parts procurement will be completed by the end of 1968, with calendar year 1969 being devoted to installation and tune-up of the accelerator and its
associated systems. It is hoped to begin trials with research equipment in the summer or fall of 1969 and some research operations during the summer of 1970.

L.N.S. COMPUTER FACILITY
As was pointed out last year, the Laboratory's computing needs had by then outgrown the capacity of its IBM 7044 computer, and plans were undertaken to replace this computer with an IBM 360/65. This computer was purchased by the Atomic Energy Commission for the Laboratory and was installed during the fall of 1967. It is now operating effectively and is used by L.N.S. staff members, as was the IBM 7044, for L.N.S. programs including those activities of the Laboratory's cosmic ray group that are involved with space research. The new computer is expected ultimately to provide about four times the computer capacity of the 7044. Factors of between three and four have been achieved already.

RESEARCH SUMMARIES

HIGH-ENERGY PHYSICS

THEORY The theoretical group has continued to work on problems of great contemporary interest. In elementary particle theory, extensive investigations of the current algebra and soft pion hypotheses have been performed and the development of a successful extrapolation method to the realistic hard pion has been obtained. Corrections to the soft pion limit for pion scattering are now being obtained. Phenomenological descriptions of elementary particle interactions involving the use of Regge theory have been applied successfully. Studies of field theory include comparison to the results obtained by the current algebra-dispersion theory technique as well as new calculations in quantum electrodynamics employing the conformal group.

EXPERIMENT The Laboratory continues to pursue an active program of experimental high-energy nuclear physics aimed at studying the nature and structure of elementary particles and their interactions. Recent efforts have been concerned mainly with deepening our understanding of the strong and electromagnetic interactions through the study of strong and electromagnetic production reactions of excited states and stable particles, and through the detailed study of the strong and electromagnetic decay of the excited states. In addition, we have investigated specifically electromagnetic processes with the object of examining the limits of validity of the theory of quantum electrodynamics.
Group summaries follow below:

The group working with Professor David H. Frisch: The program of this group is to do elementary particle physics with spark chambers at C.E.A., BNL's Alternating Gradient Synchrotron facility and soon at the national accelerator laboratory site at Batavia, Illinois after completion of that facility. At C.E.A. an internally tagged parasite beam facility is being used to study photoproduction of various mesons. Also at C.E.A. detecting equipment for colliding beam experiments on quantum electrodynamics and heavy bosons is being designed and tested.

During the past year the following was accomplished:
1. The setting of a firm upper limit on any structure in the \( \pi^+ \pi^0 \) mass spectrum below the \( \rho \)-mass.
2. The analysis of \( K^-p \) elastic charge exchange scattering and inelastic \( K^0 \) and \( \Lambda^0 \) production and the studying of the latter on a quark model.
3. The initiation of data taking on the \( K^+p \) mass spectrum, using a new method in a BNL test-beam run, and on photoproduction of mesons using our new internally tagged beam facility at C.E.A.
4. The completion of instrumenting an exceptionally difficult experiment on weak interactions (\( \Delta S/\Delta Q \) for \( K^+\pi^- \) decays) which is now being run at BNL.

The group working with Professors Jerome I. Friedman and Henry W. Kendall: This group's central interest in electrodynamics and the use of electromagnetic interactions to probe strongly interacting systems will continue to be pursued in a series of experiments involving both electron- and photon-induced processes at the C.E.A. and S.L.A.C. The C.E.A. program makes use of the long duty cycle of the accelerator to study reactions requiring coincidence detection techniques, whereas the high energy and beam current available at S.L.A.C. will be utilized to study momentum transfer processes in single reaction product experiments.

During the past year the following was accomplished at C.E.A.:
1. The study of the final state interaction in the electrodisintegration of the deuteron to provide information about the short-range behavior of the \( n-p \) interaction at low-relative energies. Measurements agree with the predictions from some of the modern hard and soft core potentials.

At S.L.A.C.:
1. Measurements have been made of the magnetic form factor of the proton, \( G_{mp} \), over a range of four-momentum transfers going up to \( q^2 = 25 (\text{GeV}/c)^2 \). The remarkable result of this experiment has been the demonstration that over the entire range of \( q^2 \) the form factor is given to a very good approximation by the dipole expression

\[
G_{mp} = \mu_p (1 + 0.71 q^2)^{-2}
\]
Thus, the indications are that $G_{mp} \propto 1/q^4$ as $q^2$ becomes very large, with still no evidence for a charged core in the proton. Furthermore, the dipole form would correspond to an exchange of two closely spaced vector meson resonances; experimentally, only the $\rho$-meson (or $\omega$- and $\phi$ for the isoscalar form factor) is a plausible candidate. There are, however, small but statistically well established deviations from the dipole formula which have, until now, no plausible theoretical explanation.

2. Measurements of inelastic electron proton scattering spectra at incident energies of 17 to 7 GeV and in the angular range of $3^\circ$ to $8^\circ$. The purposes of this experiment are: to establish the momentum transfer dependence of the form factors corresponding to the electroproduction of the excited states of the proton, to search for resonances not previously known to be excited in electron scattering, and to study the inelastic continuum region in order to compare with predictions of Bjorken. Measurements of the spectra of the scattered electrons were made from the elastic momentum to the region of deep inelasticity.

3. Measurements of the electric form factor of the proton, $G_{ep}$, up to squared four momentum transfers of $10(\frac{\text{GeV}}{c})^2$.

Researche of the group working with Professors Pless, Bernard T. Feld, and Robert I. Hulsizer: One of the objectives of this group's program is to study elementary particle interactions with emphasis on pion-proton interactions. This study is being carried out using a number of techniques, in particular, bubble chambers, counters, and spark chambers. The program represents a broad approach to pion nucleon interactions and their relevance to present theories.

During the past year the following was accomplished:

1. The completion of the analysis and publishing of the C.E.A. bubble chamber experiment on photoproduction ($\gamma + p$ interaction for 0.5-6 GeV/c photons) using a 12-inch bubble chamber at the C.E.A. accelerator.

2. The publishing of results of a counter experiment at ANL which has determined the major production mechanism of $\pi^+\pi^-$ mesons in the forward direction by incident $\pi^-$ mesons. The production mechanism seems to be mainly through $f^o$ production and there seems to be no indication of any di-proton contribution to the observed $\pi^+$'s.

3. The completion of the study of $\pi^-$ interactions on protons leading to neutral final states in the momentum range from 1 to 4 GeV/c. All neutral final states were studied. Some major programs have been written to analyze this experiment. Although complex, the analysis has pro-
ceeded at a satisfactory rate (in collaboration with the group working with Professor Lawrence Rosenson).

4. The initiation of an experiment at ANL to study the extreme backward cross section of the pion charge exchange reaction. This experiment will help determine some fundamental aspects of the Regge theory.

5. The moving to and installation at ANL of the L.N.S.-M.I.T. 500-liter liquid hydrogen bubble chamber. By May of this year the chamber was pulsed at least one million times at liquid nitrogen temperatures and operating pressures. This operation has demonstrated that the cryogenic refrigerator has greater stability than any known chamber and, in addition, the controlling range exceeds that of any known chamber.

6. The bringing of the group's high-speed bubble chamber data analysis system, PEPR, into successful operation. Although the prototype PEPR was never designed to be a production model, it has analyzed 500 events per day in routine fashion and has had peak rates of 1,000 events per day. It has already completed the measurement of all events contained in 100,000 pictures obtained with a beam of 3.9 GeV/c \( \pi^- \) mesons in the MURA 30-inch hydrogen bubble chamber at the ANL. The accuracy of PEPR as a measuring machine exceeds that of a manual measuring microscope by a factor of two. In addition, PEPR has demonstrated its ability to measure ionization in a routine fashion. PEPR has also reliably distinguished 1.2 times minimum ionization from minimum ionization. It can do this on film of widely varying quality, even when the quality of the picture varies from frame to frame. This is possible due to the unique capability of being able to vary the sensitivity of the PEPR system from frame to frame. This performance is superior to any known system. At present PEPR is the most sophisticated and reliable cathode ray tube system of its kind in the world. It should be noted also that the production model of PEPR referenced in last year's report will be delivered to M.I.T. during late summer or early fall of 1968.

7. The analysis of the \( \bar{p} p \) experiment, which is almost complete. This experiment was partially analyzed by PEPR; however, since the major portion had to be analyzed by hand, this work has gone slower than the PEPR analysis of the \( \pi^- \) film.

Researches of the group working with Professor Martin Deutsch: In addition to experiments carried out by members of this group with the support of L.N.S. and of C.E.A., the experimental program has included several collaborative undertakings with other research groups at other institutions. Scientifically, the research problems fall into two groups: photon-nucleon interactions and K-meson decays.
During the past year the following was undertaken and accomplished in photon experiments at C.E.A.:

1. Efforts directed towards the completion of the experiments on elastic scattering of gamma rays by protons (proton Compton effect) that were started in 1961. Cross-section measurements obtained at a fixed barycentric angle of 65° and in the range of 0.6-2.7 GeV of incident gamma ray energy have shown that below about 1.2 GeV the scattering is apparently dominated by nucleon resonances; at energies above about 1.5 GeV photoproduction processes seem to proceed predominantly by peripheral (t-channel) interactions.

2. Recoil polarization studies in $\pi^0$ photoproduction (in collaboration with Professor Robert H. Milburn and his group, of Tufts University) for photon energies up to about 1.7 GeV. About 170,000 events have been photographed and are now being analyzed. The recoil proton is identified and its energy measured using the SPASS (Spark Chamber Automatic Scanning System) system.

3. The preparation of an exploratory experiment designed to study lambda polarization in $K^+$ photoproduction using a magnetic spectrometer and time-of-flight techniques to identify the kaon, and a telescope of visual spark chambers and counters to observe the direction of the decay proton from lambda decay.

The following has been accomplished in the area of $K^+$ meson decays:

1. Data evaluation, in collaboration with Lawrence Radiation Laboratory (L.R.L.) of Berkeley, California, of about 100,000 decay events of $K^+$ mesons at rest taken by Dr. Rae F. Stiening, Dr. Clyde Wiegand, and co-workers in an L.R.L. spark chamber arrangement to study the following: form factors of $K_{\mu 0}$ decay, a search for $K^+ \rightarrow \pi^+ + 2\gamma$, a search for $K^+ \rightarrow \pi^+ + \gamma$ and the process $K^+ \rightarrow \mu^+ + \nu + \gamma$.

2. Preparation of an experiment to study the $Ke^+\nu\gamma$ decay mode using the AGS (Alternating Gradient Synchrotron) at BNL. This experiment will throw further light on the structure of the lepton decay interaction.

The group working with Professor Rosenson: The research program of this group (in collaboration with groups at Brown University and the University of Bari, Italy) is aimed at a study of the decay processes of elementary particles and investigations of baryon spectroscopy and strong interaction dynamics through charge exchange reactions using spark chamber techniques.

Progress over the past year includes the following:

1. The undertaking of final data processing and analysis of $\pi^-$ charge exchange data covering the energy interval 0.5 to 4 GeV. This data is vital to an understanding of $\pi^-$-nucleon interactions in this energy region.
Information on the classification of baryon resonant states is forthcoming. The onset of high-energy diffraction-like behavior of the scattering is evident and is under study with the hope of gaining some insight into, and possible discrimination between, various pictures of high energy scattering that have been advanced, such as the Regge pole model and the various liquid drop and optical models. This work is also in collaboration with the group of Professor Pless.

2. The completion of the scanning and measuring of the film relating to the study of branching ratios of the $\eta^0$ meson and the initiation of analysis. The interest in this experiment is at least twofold: to compare ratios of partial widths with various model calculations and predictions, such as those of the quark model; and to pursue the consequences of various symmetry schemes and selection rules that have been proposed.

3. Design, construction and development of a spark chamber experiment to study strongly backward charge exchange processes (150° to 180° C.M.) in the 2 to 8 GeV/c region. These processes provide an excellent way of searching for resonances and classifying them. There should emerge from this study also a clarification of the dynamics of the large momentum transfer $\pi^-$ nucleon reaction. Enough of the system will have been constructed by the end of 1968 to perform the backward $\pi^-$ charge exchange experiment.

*The group working with Professors Louis S. Osborne and P. David Luckey:* The research efforts of this group center around a study of photoproduction processes in the energy range of the C.E.A. synchrotron. From study of the variation of production cross sections with energy and angle it is hoped to learn about the mechanisms involved and about the structure of elementary particles.

During the past year the following was accomplished:

1. The completion of data analysis on the wide angle $e^+e^-$ pair production experiments. Prior to this experiment there were two contradictory results on this test of quantum electrodynamics. This experiment provided a third check and employed a technique different from the other two and involved as well a different treatment of radiative corrections. The results agree with quantum electrodynamics.

2. The analysis and publishing of data on $\pi^0$ photoproduction from 2 to 6 GeV. Taken together with lower energy data measured at DESY, this seems to show agreement with an $\omega^0$ exchange model for $\pi^0$ photoproduction.

3. In combination with a group from Southeastern Massachusetts Technological Institute (S.M.T.I.), the measurement and publishing of data on the relative cross sections of $\pi^-$ and $\pi^+$ photoproduction from neutrons.
and protons, respectively. The fact that the $\pi^-/\pi^+$ cross section ratio is about 0.4 indicates that the mechanism for production cannot be one simple particle exchange.

4. The carrying out of an experiment looking for leptonic quarks which led to a lower limit for the mass of such objects (if they exist) of 900 MeV.

5. The completion of data taken by the large-angle meson photoproduction group, headed by Professor Raymond A. Alvarez and the acquiring of spark chamber photographs of 160,000 events. Scanning will be accomplished using the SPASS automatic scanning system. Preliminary rough scanning of a small fraction of these events indicates that approximately half should be unambiguously from single pion photoproduction: $\gamma + p \rightarrow \pi^+ + n$.

6. The initiation of runs on $\eta^0$ photoproduction at forward angles by detection of their $2\gamma$ modes of decay. Most of the data has been obtained and is now being analyzed. This experiment is of importance, since it can be compared with theoretical predictions of the cross section for this process.

7. The bringing into operation of the pair spectrometer at C.E.A. It will be used to check the spectrum and polarization of a photon beam produced by an aligned diamond crystal. Such photons will be used to measure meson photoproduction by polarized photons.

*The group working with Professor Samuel Ting:* The objective of this group is to undertake photoproduction studies using the 7 GeV electron beam at DESY.

During the past year the following work was undertaken:

1. Photoproduction of $\rho^0$ on complex nucleus. The behavior of photoproduction of $\rho$ on Be, C, Al, Cu, Ag, Pb was studied at the DESY 6.2 GeV/c electron accelerator with a double arm magnetic spectrometer and counter techniques. The result of this experiment shows that $\rho$ are produced via a diffraction mechanism of the whole nucleus, that the $\rho$-N total cross section = 30 mb in agreement with the prediction of quark model calculations, and that the mass and the width of photoproduced $\rho^0$ are exactly the same as that determined from $\pi$-N interactions — in contradiction with earlier results which claim that they are different.

2. Leptonic decays of vector mesons: Measurement of the $\rho \rightarrow \pi^-\pi^+$ and $\rho \rightarrow e^-e^+$ decay made with the same apparatus at the same time enabled the group to determine uniquely the branching ratio of $\rho \rightarrow e^-e^+$ free of any theoretical assumptions with regard to the production process. The branching ratio of $\rho \rightarrow e^-e^+$ measures directly the coupling strength be-
tween $\rho$ and photon. Our value of the coupling strength agrees reasonably well with that predicted from the vector dominance model.

3. Virtual Compton scattering at high energies. In this experiment a measurement was made of the asymmetrical $e^+e^-$ pair yields produced by 6.0 GeV/c photons at the pair invariant mass $m_{e^+e^-} = \text{mass of } \rho^0$. This measurement enables the determination of the phase $\exp(i\theta)$, leading to the conclusion that the $\rho^0$ are produced via a pure imaginary amplitude in agreement with the prediction of the diffraction model.

4. Photoproduction of dipions at high energies. In this experiment a systematic search was made for new resonances with mass resolution of $\Delta m = \pm 10$ MeV/c$^2$ and with a total of $4 \cdot 10^4$ events in the invariant mass region of 900 to 1200 MeV/c$^2$. The data are currently being analyzed and it should soon be possible to make a definite statement concerning the detailed nature of the $\pi^-\pi^+$ spectrum in this invariant mass region.

5. Photoproduction of $\phi$ meson on complex nucleus. The purpose of this experiment is to study the production mechanism, to understand why the $\phi$ production cross section is so small, and to measure the $\phi$-N total cross section and compare it with the predictions of quark model calculations. A total of $2 \cdot 10^4$ $\phi \rightarrow K^-K^+$ events were taken on Be, C, Al, Cu, Ag, Ta, Pb and final data will be published by the end of this year.

6. Leptonic decays of vector mesons: the branching ratio of the $\phi \rightarrow e^+e^-$. A total of 20 events have been gathered so far. A planned total of 60 events should enable a unique determination of the coupling constant between the $\phi$ particle and the photon.

7. Photoproduction of vector mesons on hydrogen, photoproduction of $\omega$ on complex nucleus, search for $K^+K^-$ resonances, and test of quantum electrodynamics to very small distances of $m_{e^+e^-} = 1$ GeV, are being planned and will be carried out early next year.

INTERMEDIATE-ENERGY PHYSICS

As remarked earlier, the Laboratory, in collaboration with the Atomic Energy Commission, currently is in the process of completing the construction of its medium-energy high-intensity electron linear accelerator facility. This facility will include an accelerator capable of providing about 150 microamperes of electrons at about 400 MeV with a duty ratio of about 1.5 per cent, an initial (relatively unsophisticated) beam handling system, buildings to house the accelerator, one experimental hall designed to accommodate a high-resolution energy loss spectrometer system, and a small laboratory and office area. The land and about 20
per cent of the cost of the facility are being provided by M.I.T. During the next several years, the major tasks envisioned for the use of this facility relate to the design and fabrication of the following: a high-resolution spectrometer system for electron scattering studies, a large solid angle, modest resolution detector array for coincidence type experiments, and a meson physics facility to allow for exploitations of the available meson beam for nuclear structure studies.

**SUMMARY OF PROGRESS** In addition to the very intense programs of work related to the construction of the accelerator itself, the following activities were pursued by members of this group:

1. During the summer of 1968 a comprehensive study program was undertaken which had as its prime objective the exploration of the kinds of research programs that would be best suited to our facility. While a more complete account of the proceedings will be completed shortly, there was general agreement, in view of present funding limitations, that the high-resolution electron spectrometer program should have the highest priority. We have therefore proceeded accordingly, and in spite of the restrictions noted previously, we still hope to be in a position to specify most of the major design features of the spectrometer by the end of fiscal year 1968. This study also pointed up the fact that beams of low-energy mu-mesons useful for mu-mesic atom work and weak interaction physics could be generated by this accelerator with intensities far in excess of those available in existing facilities, and with intensities comparable to those anticipated at some of the new facilities now under construction. The potential for research with these beams is impressive.

The study group also pointed strongly to the usefulness of the electron facility for pion physics. The beams of pions with energies below 100 MeV were considered to be very important for nuclear structure research.

2. Accelerator research and development studies include the following: an analysis of beam break-up phenomena as they relate to the design of the accelerating waveguide and the establishment of the parameters of the initial injection system, and a complete review of radiation safety leading to some relatively minor building modifications that were endorsed by the AEC’s Radiation Safety Review Panel.

The research and development studies associated with the first item have enabled us to proceed with the fabrication of the waveguide for the accelerator and to specify the type of injection system that will allow us to initiate acceleration trials. These studies have also laid the groundwork for needed improvements to the basic injector, beam control, steering and focusing systems, which we are unable to undertake at this
time because of the very tight construction budget for this facility. These additional needs will form the basis of an accelerator improvement project request to the Atomic Energy Commission for fiscal year 1970.

LOW-ENERGY PHYSICS

THEORY  The L.N.S. theoretical group has been engaged on a number of lines of research which are current in nuclear physics. These include:
1. The theory of nuclear reactions, with particular emphasis on doorway states and intermediate structure, analog resonances, deuteron scattering and stripping, and effects of the Pauli principle.
2. Development of the nucleon-nucleon potential using the boundary condition model and soft or non-local cores.
3. Work on the use of the Hartree-Fock method for calculating the binding energy and other properties of finite nuclei. This has included some shell model calculations and the development of some estimates of effective forces for them.
4. Studies on the photoproduction and electroproduction of pions from nuclei at intermediate excitation energies and attempts at explaining the large cross sections for deuteron production in large momentum transfer reactions on nuclei.

During the past year major efforts have been expended on the calculations of properties of atomic nuclei using realistic nuclear forces. Extensions have been made of the description of intermediate structure phenomena so as to permit evaluation of the fine structure parameters, as well as a better evaluation of the intermediate resonance constant. Calculations of reactions involving light nuclei and realistic nuclear forces are in the process of being performed. Improved methods for the interaction of energetic particles with nuclei are being devised with the aim of obtaining improved analysis of high-energy experiments.

EXPERIMENT  For a number of years the Laboratory’s charged particle research program has involved research using radioactivity studies (radioactivity group) and induced nuclear reactions at three M.I.T. machines, a 7 MeV proton cyclotron (cyclotron group), an “8 MeV” Van de Graaff accelerator (nuclear energy level studies group) and a 17 MeV electron linear accelerator (LINAC group).

CYCLOTRON

The cyclotron has external beams of 30 MeV α particles, 15 MeV deuterons and 7.5 MeV protons. The facility has been set up so that nuclear reactions can be observed with good energy resolution by the use of a magnetic analysis system for the beam and solid-state detectors,
and for the reaction products, including $\gamma$ rays. The main research programs in the past several years have been concerned with the study of collective excitations of medium-weight nuclei. These states have been of considerable theoretical and experimental interest.

Research activity in the last half of fiscal year 1968 has been curtailed and no new experiments have been started. The main thrust of the research is to complete student theses and associated experiments. A transfer of physicists and technical staff from the cyclotron to the LINAC project has been started and is expected to be completed in fiscal year 1969.

Cyclotron-induced nuclear reactions have produced the following significant results from alpha-particle and proton reactions on the L.N.S. cyclotron:

1. The systematics of strongly excited states (particularly $3^{-}$ and $4^{+}$) in Zr$^{90}$, Mo$^{92}$, and Ti$^{48}$ have been completed. In addition, results in the Ge isotopes Ar$^{40}$ and Sn$^{118}$ are in progress. This completes our inelastic scattering program. A review article on this work is in progress.

2. $(\alpha, d)$ reactions on K$^{39}$ and Ca$^{48}$ have been studied.

3. Ca$^{42}(p, p'\gamma)$ experiment has been refined; data taking is complete and analysis is near completion.

4. Ti$^{48}(p, p'\gamma)$. Branching ratios and lifetimes have been measured. Analysis of data is near completion.

5. Ca$^{44}(p, p'\gamma)$ and Cr$^{52}(p, p'\gamma)$. Branching ratios and lifetimes have been measured.

6. Mg, Si, and C$(p, p'\gamma)$ experiments have been completed to check the validity of the Doppler shift attenuation technique used here.

7. Investigation has begun on Ar$^{40}(p, p'\gamma)$ for lifetime and branching ratio measurements. This nucleus has a level structure very similar to Ca$^{42}$.

8. Investigations of the use of a large solid angle, annular detector in the forward hemisphere are under way. This will allow $(\alpha, \alpha'\gamma)$ experiments using GE(Li) $\gamma$ ray detectors.

9. $(\alpha, 3n\gamma)$, $(\alpha, 3n\gamma\gamma)$ $(\alpha, 2n\gamma)$ $(\alpha, 2n\gamma\gamma)$ reactions on nuclei leading to rotational states in the residual nucleus have been carried out. This study investigates the statistical nature of the neutron and $\gamma$-ray cascades leading to these rotational bands.

10. In collaboration with the radioactivity group, the magnetic moments of excited states have been measured. In particular a state in Fe$^{66}$ excited by $(p, p')$, and states in the Dy isotopes excited by the $(\alpha, 2n)$ reaction on the Gd isotopes have been studied.

Results from $(p, d)$ and $(p, t)$ reactions using other cyclotrons (Uni-
versity of Colorado and Oak Ridge National Laboratory) are:
1. The Ca$^{42,44}$ (p,d), Ca$^{42}$ (p,t) and Pb$^{208}$ (p,t) reactions have been studied.
2. A 100 keV resolution Pb$^{208}$ (p,d)Pb$^{207}$ reaction study gave some evidence of either non-shell-model components in the Pb$^{208}$ ground state or fractionation of the one-hole strength in Pb$^{207}$. A 50 keV resolution experiment was performed at the Oak Ridge National Laboratory using the magnetic spectograph.

**LINEAR ACCELERATOR GROUP**

In past years the experimental programs included studies of energy spectra and angular distributions of neutrons from the giant electric dipole resonance of nuclei and studies of polarizations of these neutrons to achieve a more complete parameterization of the reaction mechanism. This work was extended also to measuring photoproton energy spectra and angular distributions using about 100 MeV bremsstrahlung in a study of shell structure correlations in light nuclei. These studies were carried out at the M.I.T. 17 MeV LINAC and at the accelerators at Rensselaer Polytechnic Institute and Saskatoon. As of this year, work at these accelerators has been terminated.

The neutron polarimetry techniques developed by the group are being applied to studies of polarization of 14.5 MeV neutrons elastically and inelastically scattered.

Looking forward to the use of the new 400 MeV electron linear accelerator, the group has initiated a program of collaborative research with the National Bureau of Standards (NBS) in electron scattering, photoproduction and X-ray scattering that will naturally lead to experience valuable in experimental planning for the new facility. The initial research plans center on studies of $^0$ via elastic and inelastic electron scattering. The work will be extended to include studies of the magnetic structure of the deuteron and other light nuclei with the elastic and inelastic electron scattering in the vicinity of 180°.

Efforts and progress of this past year included:
1. Intermediate-energy photoeffect: Completion of the Li$^8(\gamma p)$ work using 100 MeV bremsstrahlung.
2. Polarization of 14.5 MeV scattered neutrons: Measurement of the polarization of 14.5 neutrons elastically and inelastically scattered from C$^{12}$ for angles between 30° and 120°. The carbon data, although not complete, shows polarizations that are substantially different from those predicted by optical potential theories. It is planned to investigate other nuclei, the next target being Ca.
3. **NBS collaboration**: Targets of Be and BeO have been constructed for the first electron work at the NBS. Using 60 MeV electrons and scattering at 110° from Be0, preliminary data has been obtained up to \( \sim 13 \) MeV of inelasticity to study the problems involved in this high-resolution spectroscopy. Several states were seen and it looks feasible to separate the \( 0^+ 3^- \) doublet (80 KeV separation) at about 6 MeV. The Be background appears not difficult to measure and extract from the BeO data. Computer programs have been written to allow detailed calculations of resolution functions for the reduction of data. They account for optical resolution, radiative effects and Landow straggling.

**NUCLEAR ENERGY LEVEL STUDIES GROUP**

A central problem of experimental nuclear physics is to obtain the best possible description of the nuclear wave function of the various states of all accessible nuclides. Charged-particle reactions provide one of the most powerful tools for this task. The nuclear energy level studies group is committed to the use of its time and facilities for the study of nuclear structure by means of these reactions and to improve continuously the experimental methods and equipment involved.

In recent years, reactions initiated by hydrogen beams have been carefully studied in this laboratory for most of the available stable isotopes up to \( Z = 30 \) and on a few of the heavier elements. We now have a beam of doubly charged \( \text{He}^8 \) and can cover the same region with \( \text{He}^3 \)-induced reactions. We also have taken up work on particle-gamma coincidences and isobar-analog resonances in order to obtain additional information about the nuclear states. We intend to continue this work on the 8 MeV electrostatic generator until such time as the activity can be transferred to a higher energy machine.

During the past year the subjects covered were mostly nuclear-structure topics, as studied by reactions induced by hydrogen or helium beams. Of particular interest are the following examples:

1. Work with the \( \text{He}^{8+} \) beam at 13 to 15 MeV on various target nuclei. Emitted protons, deuterons, and alpha particles were studied with the multiple-gap spectrograph.

2. Isobar-analog studies with a proton beam. Elastic and inelastic cross sections have been measured as a function of bombarding energy. In some cases, angular distributions of inelastically scattered protons have been determined by use of the multiple-gap spectrograph.

3. Measurement of particle-gamma coincidence rates to some levels excited by inelastically scattered protons.
The continuing programs of the radioactivity group fall into three categories. First are investigations of perturbed angular correlations of Coulomb excited gamma rays. This technique, which we have called IMPACT, has been pursued vigorously in a collaborative effort with physicists at the University of Wisconsin; it is now being pursued as well in a collaborative effort with scientists at the MP, Tandem Accelerator at Yale University. The work at Wisconsin has resulted in a number of studies completed during the past year. The magnetic moments of first 2+ states of mercury isotopes and of platinum isotopes have been measured. Extensive investigations have been carried out on internal fields at nuclei of various solutes in iron, nickel, cobalt, and, most significantly, in gadolinium. This work has led to the discovery of an induced polarization of heavy ions which traverse polarized ferromagnetic domains. This new phenomenon results in a transient positive field and appears to be the result of the pickup by the ion of polarized electrons from the host. An extension of the work at Wisconsin is now in full swing at Yale University. A 90-100 MeV sulphur beam is being used for the studies of perturbed angular correlations of higher excited states than can be reached with the oxygen projectiles of the Wisconsin tandem.

A second phase of the work is the investigation of internal fields using radioactive sources. A first study of the internal fields in Type II superconductors has been completed. Magnetic moments of various states in samarium, gadolinium and lead have been obtained. Investigations of internal fields on cerium nuclei in ferromagnetic hosts have begun.

The third continuing effort is the work on isomer shifts using the Mössbauer effect. This year we have succeeded in measuring the change in charge radius between members of the rotational band in Eu^{153} as well as several even-even nuclei.

An experiment on the perturbed angular distribution of resonantly scattered radiation has terminated.

Two new projects which are allied to the above investigations have been begun this year. The first of these projects is a collaborative effort with the Cyclotron to use nuclear reactions to measure magnetic moments with the IMPACT technique. This work has resulted in one completed experiment on Fe^{56}. The technique is being pursued vigorously to measure g factors of other states in ferromagnetic materials. A second project concerns the use of perturbed angular correlations for the measurements of states fed by alpha particle decay. Previous attempts at such measurements, carried out both in this and in other laboratories, were unsuccessful due to the lack of knowledge of the solid-state phe-
nomena involved. We believe that we now understand the phenomena sufficiently so that we have a fair chance of successfully measuring a number of magnetic moments, using a modified form of the IMPACT technique.

During the past year, a considerable effort of the group was devoted to the TU Van de Graaff proposal. Experimental results were obtained on stripping and energy loss of heavy ions in foils and gas. Of particular concern were heavy ion interactions which could lead to the formation of transuranic elements. These studies are continuing, the emphasis being on the use of a proposed MP-XTU facility to be located at Burlington, Massachusetts. It is expected that the feasibility studies will continue through the year and will occupy a fair fraction of the time of the group.

COSMIC RAY AND SPACE PHYSICS

During the past year the work on X rays has been extremely fruitful, and as a result, our knowledge of those celestial objects which emit X rays has increased very significantly. Two outstanding results in this area were the identification of M-87 as an X-ray source and the discovery that several X-ray sources show large variations in intensity on time scales of minutes to weeks or months.

Work on primary cosmic gamma rays began in 1962 with the development of a detector suitable for measuring the extremely low fluxes which were anticipated. Very recently this program has been successful, and primary gamma rays in the energy range 50 to 100 MeV have been unambiguously identified. A measurement of the angular distribution is in progress.

Measurements of the Cerenkov light emitted by extensive air showers were carried out at the Mt. Chacaltaya station (17,200 feet) in Bolivia. One series of experimental data has been analyzed completely and the analysis of a second series is in progress. Also at Mt. Chacaltaya a study was made of bursts produced in heavily shielded detectors by extensive air showers. These data were compared with a theoretical Monte Carlo calculation in an attempt to obtain information concerning the composition of the primary radiation at energies of $10^{14}$-10$^{16}$eV.

PETER T. DEMOS

PROJECT MAC

ADMINISTRATION

Project MAC is an interdepartmental research facility in the computer sciences. It is supported by the Advanced Research Projects Agency.

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(ARPA) of the Department of Defense, under a contract with the Office of Naval Research, and it is presently housed in an office building adjacent to the M.I.T. campus.

The main objective for which Project MAC was organized in the early spring of 1963 was that of conducting a research and development program on machine-aided cognition and multiple-access computer systems. Since that time, the original emphasis on the development and exploitation of time-sharing systems has gradually broadened, in response to faculty and student interest, into a program of basic research in many facets of the computer sciences, as well as of computer research motivated by objectives in other fields. At the same time, research objectives and educational objectives have become increasingly intertwined, to their mutual benefit, not only in conjunction with graduate seminars and thesis research, but also in the development of undergraduate subjects of instruction in the computer sciences.

Research support is provided by Project MAC to faculty and graduate students representing 13 academic departments, in the form of access to Project MAC's computer facilities, office and laboratory space, and salary support. Data on participation in Project MAC and on the nature of support provided are given in Table I. On a full-time-equivalent basis, the research staff totals 94.8 people and the support staff totals 55.3, including 23 computer operators.

Student participation continues at an active level. During the year, 14 doctoral theses were completed with Project MAC support, 1 Engineer thesis, 13 Master's theses, and 15 Bachelor's theses.

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<th>Table I Personnel Summary and Nature of Support</th>
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<tr>
<td>Salary Office/Laboratory in Other</td>
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<td>support Technology Square participants</td>
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<tr>
<td>Faculty</td>
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<tr>
<td>Research Associates, Lecturers, Instructors, Teaching Assistants, and research staff assigned to teaching</td>
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<tr>
<td>Research Assistants and other students</td>
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<td>Research staff</td>
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<tr>
<td>Guests</td>
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<tr>
<td>Computer operators</td>
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<td>Other support people</td>
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<td>Totals</td>
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Professor Joseph C. R. Licklider of the Department of Electrical Engineering was appointed Associate Director of Project MAC, and Professor
Malcolm M. Jones of the Sloan School of Management was appointed Assistant Director. Professor Jones assumed the responsibilities previously held by Richard G. Mills, who was appointed to the new Institute position of Director of Information Processing Services.

New faculty appointments in Project MAC included Professor Licklider, Professor Robert M. Graham, and Professor Joel Moses of the Department of Electrical Engineering, Visiting Professor Seymour A. Papert of the Department of Mathematics, Professor Allen Forte of the Department of Humanities, and Professors G. Anthony Gorry Jr., David N. Ness, John F. Rockart, and Christopher R. Sprague of the Sloan School of Management. Faculty resignations included Professors Edward L. Glaser of the Department of Electrical Engineering and Martin Greenberger of the Sloan School of Management.

Professor Licklider received the Alumni Citation from Washington University in St. Louis. Professor Marvin L. Minsky was elected a member of the American Academy of Arts and Sciences and was elected a Fellow of the Institute of Electrical and Electronics Engineers. John E. Ward was also a recipient of the Fellowship Award of the Institute of Electrical and Electronics Engineers, and Professor Michael L. Dertouzos was the 1968 recipient of the J. Browder Thompson Award of the same Institute for his paper, entitled "PHASEPLOTS."

Professor Lotfi Zadeh, former Chairman of the Electrical Engineering Department of the University of California at Berkeley, spent the spring term of his sabbatical leave at Project MAC as Visiting Professor in the Department of Electrical Engineering, and Bo Alphonce, Music Director of the Institute of Musicology of the University of Uppsala, Sweden, spent the entire academic year at Project MAC as guest of the Department of Humanities. Professor Maurice V. Wilkes, Director of the Cambridge (England) University Mathematical Laboratory, paid a two-week visit to Project MAC during the spring, as he has done each year since his full-time participation in the 1963 Summer Study, and a visit of the same length was paid during the fall term by Professor Corrado Böhm of the National Institute for Computer Applications, Rome, Italy. Akio Sasaki of the Electrotechnical Laboratory, Tokyo, Japan, and Peter Schicker of the Federal Institute of Technology, Zurich, Switzerland, spent a full year as Visiting Fellows at Project MAC, working in the system research group under the supervision of Professor Fernando J. Corbató.

Project MAC's work on time-sharing systems is continuing to attract a large number of foreign visitors, both official missions formally introduced by their embassies or by the State Department, and private individ-
The list of distinguished foreign visitors included Ambassador Anatoly Dobrynin of the Soviet Union, a guest of the Provost of M.I.T.; a group of Japanese industrialists from “Japan Productivity Center,” which included the chief executives of several Japanese industries; a Parliamentary delegation from the German Federal Republic; and a Parliamentary delegation from Romania headed by the Honorable Alexandru Birladeanu, Deputy Prime Minister, visiting the United States under the sponsorship of the White House.

**COMPUTER FACILITIES**

The current time-sharing system at Project MAC (CTSS), which employs an IBM 7094 installation, began operation in the fall of 1963 as a duplicate of the system already in existence at the M.I.T. Computation Center. A great many improvements and additions to CTSS have been implemented since that time with respect to both hardware and software. In particular, many user-developed programs and subsystems of general interest have been “published” in the form of system commands for general use. Thus, the system’s capabilities have grown considerably as a direct outgrowth of its use on the part of the community. Special facilities for automating and decentralizing system management (including the accounting and billing of computer usage) and for automatic monitoring and control of performance were described in previous reports.

A summary of the system utilization over the period July 1, 1967, through June 30, 1968, is given in Table II. The small time devoted to maintenance reflects a very high level of equipment reliability and overall system performance. Direct charging for use of CTSS became effective on January 2, 1968. Since that time each person has been paying for his use of CTSS on the basis of the same rates established by the M.I.T. Information Processing Services Center on its own CTSS installation. As a result of this action, Project MAC in effect terminated its support of various research for which it had previously provided free access to its computational facilities. Roughly one-third of the system’s capacity has since been paid for from funds other than Project MAC's. It is evident from Table II that the direct charging for computer usage has not reduced appreciably the system’s load. In order to lessen the effect of introducing a direct charge, Project MAC has continued to support some individuals, particularly thesis students.

The programming of the PDP-7 computer to act as a buffer between the 7094 computer and the Electronic Systems Laboratory display system was completed during the fall, 1967. As a result, the 7094 com-
### Table II  Time-Sharing System Utilization Summary (Hours [Per cent]*)

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<tr>
<td><strong>Charged time</strong></td>
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<tr>
<td><strong>Total charged time</strong></td>
<td><strong>419[56.3]</strong></td>
<td><strong>410[55.1]</strong></td>
<td><strong>334[46.4]</strong></td>
<td><strong>384[51.6]</strong></td>
<td><strong>318[44.2]</strong></td>
<td><strong>349[46.9]</strong></td>
</tr>
<tr>
<td>Other time</td>
<td>249[33.5]</td>
<td>254[34.1]</td>
<td>329[45.7]</td>
<td>299[40.2]</td>
<td>343[47.6]</td>
<td>330[44.4]</td>
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<tr>
<td><strong>Total</strong></td>
<td>744[100.0]</td>
<td>744[100.0]</td>
<td>720[100.0]</td>
<td>744[100.0]</td>
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<td><strong>Charged time</strong></td>
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<tr>
<td><strong>Total charged time</strong></td>
<td><strong>323[43.4]</strong></td>
<td><strong>347[49.8]</strong></td>
<td><strong>283[38.0]</strong></td>
<td><strong>304[42.2]</strong></td>
<td><strong>394[53.0]</strong></td>
<td><strong>308[42.8]</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>744[100.0]</td>
<td>696[100.0]</td>
<td>744[100.0]</td>
<td>720[100.0]</td>
<td>744[100.0]</td>
<td>720[100.0]</td>
</tr>
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*Base = Total number of hours in month

**On-line time is the computer time used by people operating from remote terminals.
Background time is the computer time used by conventional batch execution of programs.
Computer has been relieved of many time- and memory-consuming tasks which it previously had to perform in conjunction with the operation of the display system. These tasks include the storing of the display list, the interpretation and servicing of interrupts caused by the light pen and by other control devices available to the user, and the execution of real-time programs required to perform certain transformations of the picture displayed, such as rotation of a three-dimensional picture.

The development of ARDS (Advanced Remote Display Station) has been completed, and a prototype has been in use as a terminal of CTSS for some time. Several repackaged and slightly improved units are on order from an outside vendor and will be delivered during the summer of 1968. The first of these units is expected to be operating through a transatlantic connection in Berlin at the time of the M.I.T.-T.U.B. (Technical University of Berlin) Symposium on Computers in Universities which will take place during the last two weeks of July, 1968. ARDS includes a storage display tube, circuitry for character generation and line generation, and control devices for pointing to elements of the picture and for drawing. It has a resolution of about 100 points per inch and can display 50 lines of text, each consisting of up to 80 characters. Since this terminal can operate through a normal telephone line, it can be installed very quickly in any location just as a teletypewriter.

The artificial intelligence group has developed a simple time-sharing system for its PDP-6 computer to facilitate and speed up the programming effort in the Visually Controlled Manipulator Project. This time-sharing system has been in daily use for almost a year. It employs the very large memory (250,000 words) acquired during the preceding year. Since the PDP-6 computer is used most of the time for real-time experiments, a PDP-10 computer (a faster version of the PDP-6 computer) has been acquired during the past year and is now in regular operation. This additional computer will permit the programming effort to proceed parallel with real-time experimentation.

The General Electric 645 computer installation has been in operation throughout the past year, although used solely for the development of the Multics Time-Sharing System. The last peripheral unit of the installation, a disc file, was delivered in January, 1968. Some of the units will be replaced by improved models by the end of this summer. The installation includes two central processors, two input-output controllers, and several banks of core memory, and it is currently being operated for system programming and check-out purposes as two independent systems.
PROJECT MAC

RESEARCH PROGRAM

In addition to its own research program, Project MAC has been providing partial support to research in various M.I.T. departments and laboratories in the form of access to its computer facilities, office space, and, in some instances, salary support to particular individuals. Such research is reported by the individual departments and laboratories that provide the primary support. Project MAC’s own research program includes two large group efforts: the Multics Project and the Visually Controlled Manipulator Project. In addition, it includes a wide variety of research carried out by individual members of the Faculty and their students. Some of this research is closely intertwined with the development of new undergraduate and graduate subjects; these related efforts are helping each other in a very significant way, with the educational effort giving rise to new research topics and the research effort feeding back new material for instruction, and above all a better understanding of the issues involved.

MULTICS

The design implementation of the Multics System is being carried out by the system research group under the leadership of Professor Corbató, in collaboration with the Bell Telephone Laboratories and the General Electric Company. This totally new time-sharing system is being implemented on General Electric’s 645 computer, but it is intended to be transferable to other computers with similar characteristics. Professor Corbató represents Project MAC in the technical committee supervising this joint research and development program, and Robert C. Daley of Project MAC is in over-all charge of the implementation effort.

The system design is described in detail in the Multics System Programming Manual, which includes by now more than 3,000 pages of English text. The operating system is programmed in a subset of the language PL/1, a fact which is greatly facilitating the detection and correction of design errors, the improvement of parts the performance of which has been found to be unsatisfactory, and will undoubtedly aid in the future evolution of the system. A major milestone was reached in December, 1967, with the successful integrated check-out of a critical part of the system representing approximately one-half of the operating system software. By the end of June, 1968, most of the parts of the system necessary for initial operation had been integrated and checked out, but analysis of the system’s operation indicated that various parts had to be modified and in some cases redesigned to achieve a satisfactory
level of performance. Major improvements of performance have already been achieved, and further significant improvements are expected to result from modifications currently in progress.

The expectation a year ago was that a limited version of the Multics System would be in daily operation early in 1968. This expectation proved to be unrealistic, and it appears now that this point would be reached very likely by the end of 1968 and possibly by mid-fall. This misestimation of schedules by a factor of two has been characteristic of the Project since the beginning. It is by no means unusual in large software efforts and results primarily from the great variety of unforeseen events, some as trivial as clerical mistakes, whose probabilities of occurrence become rather high when hundreds of interacting software modules are involved. In addition, it has become evident that in a complex operating system such as Multics, the first coding of any particular module should be regarded as equivalent to a detailed design specification. It is only after many modules have been integrated and the logic of their interactions has been checked out that it becomes possible to implement the necessary functions in an efficient manner. It has been suggested that implementation of intricate system functions is somewhat analogous to proving mathematical theorems. Most often, it is only after developing an awkward proof that the issues involved become sufficiently clear to permit the development of a concise, elegant proof. These remarks have been made because the technical management of large software efforts is at present a very poorly understood art, and a significant part of the new knowledge and insight about computer system design generated by the Multics research effort is indeed in this area.

Professor Elliott I. Organick of the University of Houston has drafted additional chapters of the "Guide to MULTICS for Sub-System Writers." He is expected to complete this work during the year 1968-69 when he will be at M.I.T. as a Visiting Professor in the Department of Electrical Engineering. The chapters currently available have been used during the past spring in a second graduate seminar on the Multics System led by Professors Jones, Gorry, and Sprague of the Sloan School of Management and Dr. John W. Brackett of the Department of Metallurgy and Materials Science.

VISUALLY CONTROLLED MANIPULATOR

The objective of this project is to learn how to endow computers with general-purpose "eyes" and "hands" capable of observing and manipulating the physical environment. A research effort in this direction has been in progress since the summer of 1965 under the leadership of Pro-
fessor Minsky of the Department of Electrical Engineering and Professor Papert of the Department of Mathematics. A first measure of success was obtained in early fall, 1966. The system, consisting at that time of a modified industrial manipulator, an image disector camera, and a PDP-6 computer, was able to construct, without human intervention, a tower from cubes of different sizes thrown at random on a table. In order to proceed to more elaborate and difficult tasks, major equipment improvements were needed, and above all a better understanding of the problems of automatic scene analysis. A major part of the group’s effort has been devoted during the past year to understanding the vision problem, that is, the relations between spatial geometric situations and optical measurements. As this body of knowledge is developed, it must be represented in the computer programs that have the goal of analyzing pictures into three-dimensional structures. Therefore, a second concern has been the development of problem-solving programs that can manage spatial geometric information. This requires novel representation methods, and a substantial body of work has been done on the theory of two-dimensional automata, in the hope that it may provide some insight into the problems involved.

An important piece of theoretical work has been completed by Professors Minsky and Papert on the pattern recognition capabilities and limitations of perceptrons. Part of this work has been published in a major paper entitled “Linearly Unrecognizable Patterns,” and an M.I.T. Press monograph, currently in press, will provide a complete exposition of their work.

Major equipment improvements have been carried out parallel to the theoretical and programming effort. A new image disector camera has been completed with substantially greater sensitivity and resolution. Similarly, a new mechanical arm and hand combination has been completed, embodying many more degrees of freedom and substantially better control capabilities for object manipulation. Pressure sensors are currently being incorporated in the hand.

OTHER RESEARCH TOPICS
The rest of the research program consists of many separate topics of interest to individual members of the Faculty and their students the individual descriptions of which are beyond the scope of this report. Only a few illustrative examples are given below. A doctoral thesis entitled “Symbolic Integration” was completed by Joel Moses, presently Assistant Professor in the Department of Electrical Engineering, under the supervision of Professor Minsky. A product of this thesis is a pro-
gram that can perform symbolic integration at the level of a competent mathematician. It uses heuristic techniques similar to those used by people; for instance, it inspects the integral to decide what approach, such as integration by parts or substitution of variables, is most likely to simplify the integral, and changes approach if the integral is not thereby simplified. A very interesting aspect of this program is that it stores significant knowledge about calculus in the same sense that a book does, but with the very important difference that such knowledge can be used directly without being first absorbed and practiced by a person. This thesis is a part of a broader research effort aimed at the development of a subsystem for on-line mathematical analysis that could be used effectively as a skillful mathematical assistant.

The computation structures group, under the leadership of Professor Jack B. Dennis of the Department of Electrical Engineering, is studying fundamental aspects of the representation of computation processes and information structures, and their application to the organization of general-purpose computer systems. During the past year much of the group's effort was focused on parallelism — both in the description of computations and in the functional organization of computer hardware. Two recently completed doctoral theses have developed new insights into these areas. The work of Jorge Rodriguez-Bezos examines formal properties of graph representations of programs; the work of Fred L. Luconi studies the modular structure of asynchronous systems of digital logic. Professor Dennis has developed a general model for information structures and has proposed an unusual highly parallel machine organization based on the model. A third doctoral dissertation, that of Peter J. Denning, studies principles of memory management and scheduling in multi-access computing systems. The research of the group interacts strongly with the development of an undergraduate computer science program in the Department of Electrical Engineering. The subject Computation Structures, in particular, has been influenced substantially by the research carried out in this group.

Professor Zvi Kohavi of the Department of Electrical Engineering and his students have been studying various problems associated with the design of finite-state machines having fault detection capabilities, and with the general areas of reliability improvements and machine diagnosis. Several results have been obtained which lead to shorter and more efficient fault detection tests.

Professors Joseph Weizenbaum and Robert P. Fenichel of the Department of Electrical Engineering have developed a program for computer-aided instruction in programming under the joint sponsorship of
the Department of Electrical Engineering and Project MAC. This program has been used successfully by students in the spring term, and an improved version is currently being developed for use in the fall term, 1968.

As stated above, these are only examples of research completed during the past year. A complete description of Project MAC's research program will appear in its Yearly Progress Report.

ROBERT M. FANO

RESEARCH LABORATORY OF ELECTRONICS

This interdepartmental laboratory provides facilities for academic research covering a large range of topics, most of which fall into one of three broad categories, designated as general physics, plasma dynamics and communication sciences. During the past year, 113 faculty members, 304 graduate students and 75 undergraduates from 16 academic departments participated in the program.

The research during the past year has resulted in the publication of 120 journal articles and 12 technical reports. In addition, the research provided the basis for 55 doctoral, 15 Engineer, 48 Master's and 45 Bachelor's theses. The total number of degrees based on theses supported by the Laboratory since it was founded now stands at 2,598, of which 590 were doctoral, 112 were Engineer, 858 were Master's and 1,038 were Bachelor's.

Major support for the research is provided by the Joint Services Electronics Program of the Army, Navy and Air Force as well as the Atomic Energy Commission, the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration.

The following sections summarize the research activities of the past year.

GENERAL PHYSICS

The research in general physics includes a variety of activities, many of which are based on atomic resonance phenomena. The experimental techniques required to observe these basic properties of matter and to exploit them in engineering applications span most of the electromagnetic spectrum from radio wavelengths to X rays. Other experimental requirements include the use of extremely high frequency vibrational waves, the use of liquid helium temperatures, and extensive use of computers.
The molecular beam group, supervised by Professor John G. King, is continuing studies of atoms evaporating from liquid helium. Previous measurements which revealed an anomalous high temperature associated with the atoms evaporating from liquid He II will be extended. It is also planned to study the evaporation from superfluid films, from mixtures of He³ and He⁴, and from helium in rotation. A dilution refrigerator capable of reaching 0.1° Kelvin, three cryostats with associated pumping and gas handling equipment and three molecular beam apparatuses are nearing completion.

The microwave spectroscopy group, under the supervision of Professors Malcom W. P. Strandberg and Robert L. Kyhl, has developed a model for the dependence of the radio-frequency magneto-impedance of metal single crystals on the electron mean free path and on the dependence of the specular reflection coefficient on the electron momentum transfer at the metal surface. Measurements of the radio-frequency surface magneto-impedance of tin and gallium support the theory, and the method is providing a versatile approach for the investigation of these parameters.

The radio astronomy group, under the supervision of Professors Alan H. Barrett, Bernard F. Burke, David H. Staelin, and Richard M. Price, has actively pursued several lines of investigation.

Professors Barrett and Burke and their students have applied the techniques of phase coherent, very long-baseline interferometry to the study of hydroxyl (OH) radio emission from galactic sources. The determination of the angular sizes of the OH emission regions required the use of independent radio telescopes and receivers for simultaneous observations using atomic frequency standards at each observatory for phase synchronization. Radio telescopes in Massachusetts, West Virginia, California, and Sweden were necessary to establish angular sizes as small as 0.005 seconds of arc.

Professor Burke has recently completed a study of hydrogen radio recombination lines from galactic thermal radio sources and correlated the results with previously determined models of galactic structure. Professors Burke and Price are currently building an array of 16-meter radio telescopes to observe the newly discovered pulsating radio sources.

Professor Barrett has performed observations of atmospheric microwave emission from the molecular oxygen resonances at about five millimeters wavelength. The observations are carried out at altitudes of 100,000 feet or more, using balloons launched at the Palestine, Texas, flight facility of the National Center for Atmospheric Research. The observations are to determine the temperature profile of the atmosphere
from remote microwave measurements and are intended to serve as a precursor for meteorological satellite experiments.

A measurement of the microwave background radiation, presumably the remnant radiation of the primeval fireball, was made at 9.24mm wavelength by Professors Staelin and Burke.

Professor Staelin has also been engaged in the measurement of atmospheric line profiles of water vapor and ozone, and is currently engaged in the construction of a multichannel radiometer to pursue the study of weak atmospheric lines.

The solid-state microwave electronics group, under the direction of Professor Robert P. Rafuse, is continuing its activities in the area of high dynamic range instrumentation with a preliminary high-frequency mixer design having third-order distortion products 120 decibels below a milliwatt two-tone input. A completely solid-state receiver at 60 Gigahertz is under construction with a noise figure design goal of 4 to 6 decibels. Theoretical and experimental studies are under way on mixers, frequency multipliers, IMPATT and "anomalous-avalanche" diode oscillators and general technology associated with high dynamic range, low noise instrumentation for transmitters, receivers, and signal processing systems.

The electronic instrumentation group, supervised by Dr. Donald H. Steinbrecher and Professor Jerome I. Glaser, has concentrated on improving the resolution of a precision mass spectrometer. A double-focusing high-resolution spectrometer was housed in a wrought-iron electromagnetically shielded environment and mounted on an air support system to isolate building vibrations. Computer simulation of the particle flight path permitted studies of power supply interference effects on resolution. New low-noise power supplies are now being built to increase both the resolution and the long-term stability of the system. Various detection schemes are also being studied in order to provide the instrument with real-time readout and a direct interconnection with a digital computer.

Professor Clive H. Perry and his associates in the optical and infrared spectroscopy group have been investigating several mixed crystal systems, NaTaO₃-KTaO₃, KTaO₃-KNbO₃, using infrared and Raman spectroscopy over a wide temperature range (1.5 - 900°K). The optical phonons provide information on the instability leading to certain phase transitions and the lattice dynamics related to the ferroelectric behavior in these materials.

During the past year, Professor Rainer Weiss and Dr. Shaoul Ezekiel of the gravitation research group have succeeded in observing a resonance fluorescence induced by an argon ion laser in a molecular beam of iodine. The resonance is intended to serve as a reference frequency to
provide long-term stabilization of the oscillation frequency of the laser to a few parts in a trillion.

Professor Hermann A. Haus and his students have measured the pulse response of a CO₂ laser amplifier (at 10.6 microns) and have obtained agreement with theoretical principles. The input pulses, produced by a gallium-arsenide electro-optic modulator, had rise and fall times less than a nanosecond. The amplified pulses had rise and fall times of the order of 10 to 30 nanoseconds.

Professor Robert E. Stickney, Drs. Marion L. Shaw and Terence J. Lee, and their students worked on several problems relating to the physics and chemistry of solid surfaces. Experimental data were obtained on the effects of various adsorbates (Cs, K, Na, O, N₂ and H₂) on the work functions of single-crystal, metallic surfaces. Two molecular-beam systems were constructed, one for determining the rate of desorption of alkali-metal atoms from metallic surfaces, and the other for studying the scattering of gas molecules from solid surfaces.

Dr. Gary D. Bernard, in collaboration with Dr. William H. Miller of the Yale University School of Medicine, has discovered three new contrast filtering structures in insect compound eyes. These are reflection interference filters in the butterfly, diffraction filters in the skipper, and transmission interference filters in some flies. In a doctoral thesis by John L. Allen, a new waveguide mode theory for optical functioning of the so-called superposition compound eye has been evolved. The group has recently succeeded in making direct observations in support of this theory.

Professor Karl U. Ingard and his associates have observed and studied thermally excited vibrations on the surface of a liquid by means of spectral analysis of laser light scattered by these vibrations. In the optical heterodyne technique used in the experiment, the scattered light, which is frequency-modulated by the surface waves, is mixed with a portion of the incident light at a photodetector. The output of the photodetector, which contains the beat frequency between the two signals, is analyzed by means of an ultrasonic spectrum analyzer.

**PLASMA DYNAMICS**

The research in plasma dynamics includes the basic physics of gas discharge and plasmas, the generation of highly ionized plasma by electron-beam injection, studies of solid-state plasmas, and a number of potential applications such as ion propulsion and controlled fusion. Microwave, infrared and optical techniques are used extensively as diagnostic aids in studying the properties of plasmas.

The plasma physics group, under the supervision of Professors George
Bekefi, Sanborn C. Brown, John C. Ingraham, Bradford L. Wright, and Dr. Wallace M. Manheimer, continued basic studies of plasma wave interactions, instabilities and turbulence.

Dr. Manheimer has completed a theoretical study of the radiation and scattering from a turbulent plasma. He is now investigating the characteristics of certain types of non-linear instabilities.

Professors Wright and Bekefi have constructed a novel type of quiescent, collisionless plasma for the purpose of investigating the coupling of large amplitude waves in such a medium.

Professor Brown and his students are studying the absorption of infrared radiation by ionized gases.

The active plasma systems group, under the supervision of Professors Louis D. Smullin, Abraham Bers, Richard J. Briggs and Ronald R. Parker, has continued its experimental studies of the beam-plasma discharge, and theoretical studies of linear and non-linear wave interactions in plasmas.

The work of Professor Smullin, Rulon K. Linford, and Joseph A. Mangano has been concerned with investigating the power transfer from a high-power electron beam to a plasma in a beam-plasma discharge apparatus located in the Francis H. Bitter National Magnet Laboratory. Measurements of the plasma diamagnetism have shown that energy densities up to $10^{15}$ electron volts per cubic centimeter have been obtained with beam-power in excess of 100 kilowatts. It has been found that most of the energy resides in a group of suprathermal electrons with energies far in excess of the beam voltage (ten kilovolts). Ion energies have been measured by both spectroscopic and retarding-potential probe methods and found to be in the range of one or two electron volts with continuous gas feed, and five electron volts pulsed gas feed.

The effect of multipole stabilization on a beam-plasma discharge has been studied in a smaller beam-plasma system by Professor Parker and Felipe N. Herba. It has been found that relatively modest currents in a hexapole winding stabilize a class of low-frequency instabilities which heretofore have plagued the beam-plasma discharge.

The non-linear dynamics of some plasma phenomena have been studied by computer simulation techniques by Professor Bers, Jon A. Davis and Herman M. Schneider. Such a study of the beam-plasma interaction has revealed the detailed development of the non-linear regime in which plasma electrons become heated. This study shows the importance of plasma containment and plasma homogeneity along the beam for efficient heating to occur. Another study concerning the oscillations of a bounded, inhomogeneous plasma has shown the detailed non-laminar dynamics
which are responsible for the collisionless damping that is observed of such oscillations.

During the past year Professors Bers and Bekefi formed a new group to study plasma effects in solids. The interests of the group are in non-equilibrium effects that show promise for new electron device applications. Noise and coherent radiation from 30 MHz to 10 GHz have been observed in n-type InSb at $77^\circ$ Kelvin, when parallel electric and magnetic fields (3 to 20 volts/cm, and 700 to 3,000 Gauss) are applied. Experiments are being conducted to determine the mechanism responsible for these emissions. Theoretical studies of electron-phonon interactions have shown microwave amplification of acoustic waves to be feasible in acoustically active materials with high mobility, such as InSb, in the presence of a DC magnetic field which reduces electron diffusion.

Plasma physics and engineering studies conducted by Professors Thomas H. Dupree, Elias P. Gyftopoulos, Lawrence M. Lidsky, and their associates include theoretical investigations of fundamental plasma properties, experimental studies of diffusion in highly ionized plasmas, and various engineering applications of plasma principles. A non-linear theory developed by Professor Dupree has accurately predicted many of the non-linear properties of unstable drift waves including saturation amplitudes and cross-field diffusion. Professor Gyftopoulos is investigating the possibility of extending his work on surface interactions to fluid-solid interfaces. Professor Lidsky and Denis C. Colombant have completed the first stages in an engineering study of a neutron source that might be capable of furnishing fluxes of $10^{14} n/cm^2$-sec in steady operation. The first stage in the 10.6$\mu$ Thomson scattering experiment has been completed with the observation of a scattered signal from the low-density hollow cathode discharge plasma.

**COMMUNICATION SCIENCES AND ENGINEERING**

The research in communication sciences includes topics related to natural and man-made systems and interactions between them. A major portion of the effort is devoted to the combined program of research and training in communications bio-engineering. This program will increase the number of individuals with the dual backgrounds needed to provide a high order of competence in applying engineering skills to the solution of problems in biology and medicine. The training aspects of the program include predoctoral training of electrical engineering graduate students and postdoctoral training for those with backgrounds in the life or health sciences. The research base for the training is provided primarily by the
R.L.E. activities in communications biophysics, neurophysiology, cognitive information processing, and speech communication.

The communications biophysics group, under the direction of Professors Walter A. Rosenblith and William M. Siebert, continued its studies of the physiological and behavioral implications of neuroelectric and other activity observed in various sensory systems, particularly the auditory system.

Research in psychophysics, supervised by Nathaniel I. Durlach, has focused on binaural hearing and perception of intensity relations. The research on binaural hearing has led to an increased knowledge of our capabilities to localize sound sources and to detect signals in backgrounds of interference, and of how these capabilities are limited by imperfections in the peripheral transformation from acoustical waveforms to neural firing patterns in the auditory nerve. The research on the perception of intensity relations has provided further insight into how our capabilities to detect, discriminate, identify and scale are related to each other and to fundamental limitations of sensitivity and memory.

Dr. Robert D. Hall has completed several studies of brain activity in the behaving animal, describing changes in acoustically evoked potentials in the auditory pathways of the rat as a function of sleep and waking, and as a function of several drug-induced state changes. Professor Stephen K. Burns and his students have developed a number of instruments and techniques that are useful for processing EEG and EKG records. A technique has been devised by Professor Richard W. Henry for recording from sensory and motor nerve cells in crayfish while the animal is relatively free to respond reflexively to various sensory inputs. Several important studies of the dynamic and fluctuating properties of nerve membrane have been completed by students of Professor Thomas F. Weiss. Professor Peter G. Katona (in association with Dr. G. Octo Barnett of the Massachusetts General Hospital) has succeeded in describing quantitatively certain components of the system which cause reflex changes in heart rate as a result of variations in blood pressure.

Several experimental projects were carried out by members of the group in the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary. Measurements of responses in the auditory nerve of cats have led Dr. Nelson Y.-S. Kiang (with Dr. Julius L. Goldstein, from the Laboratory of Psychophysics, Harvard University) to conclude that certain subjective combination tones could result from non-linear processes in the inner ear. Professor Michael L. Wiederhold has determined the effect of stimulation of the efferent olivocochlear bundle on the responses of single auditory nerve fibers. Professors T. F. Weiss and
William T. Peake (with Dr. Harvey Sohmer, on leave from Hadassah Medical School, Jerusalem) have measured electrical responses from within the inner ear to determine the relationship of these potentials to acoustic stimuli. Some aspects of the organization of cells in the superior olivary complex have been determined through coordinated physiological and anatomical work, in cooperation with Dr. R. Kent Morest, Department of Anatomy, Harvard Medical School.

During the past year Professor Jerome Y. Lettvin and his associates in the neurophysiology group have accumulated evidence which indicates that the terminal tree of a neuron acts as a shaped filter for the statistics of interpulse intervals in the axon itself. The notion, if generalized, transforms violently our present concepts of the operation of a nervous system.

In the cognitive information processing group, the acquisition of two new data processing systems has greatly enhanced the power of our research facilities for biological image processing and for sensory aids research. The purpose of the work on biological image processing is to develop automatic objective procedures useful in clinical pathology and in biological research. Professor Murray Eden, Dr. Oleh J. Tretiak, Dr. James E. Green, and their students, are experimenting with digital procedures for the high-speed data acquisition and analysis of biomedical images, including peripheral blood smears (for both leukocytes and erythrocytes), vaginal smears (for cervical cancer), and chromosome spreads.

In the area of sensory aids, Professors Samuel J. Mason, Francis F. Lee, Donald E. Troxel, and their students are developing an improved free-standing version of a reading-machine system capable of scanning and recognizing printed text and producing artificial speech output. The system will be used in studies of the capabilities and requirements of blind subjects as users of such reading machines.

The speech communication group, under the supervision of Professor Kenneth N. Stevens, has continued to examine the nature of the speech production and perception processes, and to apply knowledge in these areas toward the development of machines for the synthesis and recognition of speech. During the past year, analyses of the acoustic properties of speech sounds and experimental data on speech-sound perception have led to more quantitative definitions of the quantal feature-generating capabilities of the vocal tract and the feature-detecting attributes of the speech perception mechanism. These findings are being complemented by studies of the process whereby children acquire the capability to perceive and to generate the sound sequences of speech. These and other experimental studies have been enhanced recently by the acquisition of new
computer facilities for the examination and display of speech data, for
the manipulation of speech signals, and for the simulation of various as-
pects of the speech process.

The linguistics group, headed by Professors Noam A. Chomsky and
Morris Halle, has continued its work on the whole range of linguistic
phenomena, from the logical bases of the theory of language to particular
phonetic phenomena in specific languages. During the year an important
discussion developed which concerns the most fundamental problems in
the theory of syntax. This discussion has pointed up the need for a review
of certain problems that were thought to have been settled and has al-
ready resulted in a number of new insights into syntactic phenomena.
Among the more important works completed during the year were: Pro-
fessor Chomsky, "Remarks on Nominalizations"; Professor Halle, "On
Meter and Prosody"; Professor Kenneth L. Hale, "Preliminary Remarks
on Walbiri Grammar"; Professor John Robert Ross, "On Declarative
Sentences"; James W. Harris, "Spanish Phonology" (doctoral disserta-
tion); John R. Ross, "Constraints on Variables in Syntax" (doctoral
dissertation); and James L. Fidelholtz, "Micmac Morphophonemics"
(doctoral dissertation).

The information processing and transmission group has been concerned
with efficient and reliable communication techniques. Professors Robert
S. Kennedy and Estil V. Hoversten and their students have been working
on the efficient utilization and fundamental limitations of optical com-
munication channels. They have developed both coding theorems and
near-optimum communication techniques for such channels with an em-
phasis on atmospheric turbulence, clouds, and quantum limitations. Pro-
fessor Robert G. Gallager and his students have made advances in the
areas of sequential decoding, source coding subject to a fidelity criterion,
and error correction on burst noise channels.

The detection and estimation theory group under the supervision of
Professor Harry L. Van Trees continued work in the area of optimum
signal processing. The major emphasis was on the utilization of state-
variable and Markov process techniques to solve processing problems in
radar, sonar, and communication systems. In addition to the research
effort, current results have been organized into a coherent theory for
presentation to graduate students and practicing engineers. This latter
effort was published as a two-volume set, Detection, Estimation, and
SPECTROSCOPY LABORATORY

During the past year the research staff of the Spectroscopy Laboratory made good use of its high-resolution facilities and its laser sources. Spectroscopic studies were carried out on materials ranging from gaseous atoms to proteins and polynucleotides, and the spectra spanned the range from the ultraviolet to the submillimeter waves of the far infrared.

Professor George R. Harrison has continued the development of the two interferometrically controlled ruling engines in an attempt to make available more powerful diffraction gratings than are now obtainable. The smaller, 16-inch ruling engine is in regular operation and its output has now attained the quality level of the 10-inch gratings produced on the first interferometrically controlled engine. Remaining problems have to do with the reduction of residual vibrations in the delicate controlling machinery. It is expected that this second instrument can be transferred to an industrial firm for routine production within about a year.

The larger ruling engine, designed to produce gratings up to 24 inches in ruled width, is in the final testing stage, and indications are that it will be capable of furnishing the sustained precision needed for producing gratings of three times the power and 12 times the output of the best available at the beginning of this program. Solution of the mechanical problem of covering the surface of a reflecting mirror with more than a hundred thousand engraved grooves of controlled shape and suitable spacing involves the application of techniques such as oscillating crystal thermometers which measure to $10^{-4}$ degrees, lasers stabilized within one cycle in $5 \times 10^8$ over a two-week period, and the maintenance of a diamond cutting edge of uniform section while 50 miles of grooves are being inscribed.

The studies of Professor Richard C. Lord and his associates in the far infrared have made extensive use of the high resolution afforded by the Jarrell-Ash double-beam spectrometer. Dr. Roger Lake has examined the spectra of a number of molecules with internal potential-energy functions of special interest, including methanol, methyl ethyl ether and disilyl ether. Lionel A. Carreira has succeeded in analyzing the quite complex inversion spectra of the cyclic imines azetidine and pyrroline, which analysis yielded detailed potential curves for the inversion of these molecules. Without the high resolution of the far-infrared instrument, these spectra could not have been interpreted. Constantin C. Milionis has succeeded in observing for the first time the fine structure in the far infrared absorption of carbon suboxide. The puzzling mid-infrared absorption of this molecule has thus far defied analysis, but
it is hoped that the understanding of the low-frequency structure now resolved will enable the entire spectrum to be interpreted.

Professor Alexander Rich and Professor Lord have continued their collaboration in the spectroscopic study of molecular association of biologically important compounds. In conjunction with Dr. Yoshimasa Kyogoku, Dr. Soon Ng and Nai-teng Yu they have examined the association by means of hydrogen bonding of various drugs and the DNA bases and have found evidence for especially strong bonding between the barbiturates and adenine derivatives. The binding between certain DNA base pairs in the crystalline state has been investigated in the far-infrared by Dr. Issei Harada.

The study of laser-excited Raman spectra of biological molecules has produced interesting results. The earlier Raman work of Professor Lord and Dr. George J. Thomas Jr., showing the absence of strong association between guanine and cytosine at 1M concentration in aqueous solution, has been confirmed by the laser studies of Mr. Yu. In addition he has obtained excellent spectra of polyriboadenylic acid in water as a function of pH, and has been able to distinguish between the single-strand and double-strand forms of this material. Quite good spectra of the enzyme lysozyme have been obtained and work is now under way to see what structural information can be obtained about lysozyme in the presence of various substrates.

Professor Carl W. Garland and his students have extended their spectroscopic studies of phase changes in crystals to the infrared spectra of NH$_4$Cl, ND$_4$Cl, NH$_4$Br, and ND$_4$Br. At 21°K, the spectra consist of numerous sharp, intense bands. These bands are assigned to infrared active fundamentals and combinations involving internal modes of the ammonium ion, librational modes of the ammonium ion, and intrinsic vibrations of the crystalline lattice. New information about the phonon spectra could be obtained from combination bands involving $v_4$ and various lattice modes. Barrier heights for the hindered rotation of the ammonium ion were calculated to be 5.32 kcal mole$^{-1}$ for NH$_4$Cl and ND$_4$Cl and 4.35 kcal mole$^{-1}$ for NH$_4$Br and ND$_4$Br, though the potential model is not sufficiently anharmonic to reproduce the observed frequencies exactly. The intensity of the $T_2$-bending vibration of the ammonium ion was also studied. The regions of the lambda transition in NH$_4$Cl and NH$_4$Br were examined, and the variation of the intensity of an anomalous high-frequency component was correlated with the breakdown of translational symmetry due to disordering. The ordered cubic phase of NH$_4$Br was also studied at low temperatures and was observed
to become appreciably disordered before transforming at 108°K into the ordered tetragonal phase.

Professor Clive H. Perry and his associates have continued their infrared and Raman studies of solids. Dr. Robert P. Lowndes and John F. Parrish have completed the interpretation of the vibrations and crystal symmetry of the trifluorides of lanthanum, cerium, praseodymium and neodymium as a function of temperature, and are continuing investigation of low-lying electronic transitions of paramagnetic ions in several rare-earth-fluoride host materials at low temperatures. Jeanne H. Fertel and King Owyang have observed two-mode behavior in KI-RbI mixed crystals, and these results have been compared with one-mode behavior in KC1-KBr mixed crystals. Neal E. Tornberg has been studying the optical phonons in lead titanate and solid solutions of sodium and potassium titanates and of potassium niobate and titanate through the various ferroelectric phase transitions from 4 to 900°K.

Professor Jeffrey I. Steinfeld and his students have carried out several high-resolution optical analyses on the 5-meter echelle spectrograph in the Spectroscopy Laboratory. Absorption lines in the visible spectrum of molecular iodine which coincide with exciting lines of the Cd-I arc and the Ne-I and Ar-II lasers have been identified, and the analysis of this spectrum has been extended to high vibrational levels near the molecular dissociation limit. Also, the second 12-meter Czerny-Turner spectrograph is presently being refitted for photoelectric recording of absorption spectra. This will be used for optical line-broadening studies, and for double resonance experiments involving the effects of infrared laser pumping on the optical absorption spectrum of a variety of molecules.

Professor George B. Benedek and his associates have continued their studies of laser-excited Brillouin spectra with the 10-meter Czerny-Turner spectrometer in the Laboratory. This work is included in the account of Professor Benedek's work which appears under the report for the Center for Materials Science and Engineering.

Spectroscopic studies by Professor Ali Javan and the optical and infrared laser group have included the use of the effect of the linewidth narrowing of a high-gain amplifying transition, for the first time, in high precision wavelength measurements in which normally overlapping spectral lines are resolved. This experiment was done on an ultraviolet emission band from an excited electronic state of N₂. The high-resolution data also yield detailed information on electron excitation mechanisms. Another series of experiments studied the frequency spectrum of the spontaneous emission arising from one of the levels of a laser-saturated
optical transition. Viewed along the axis of the laser beam, the laser-induced change signals are virtually free of Doppler broadening. The observed change signals are being utilized in precision isotope shift measurements and in line-shape studies in neon.

Visiting scientists working in the Laboratory during the past year included Dr. Issei Harada, University of Tokyo; Dr. Roger Lake, Oxford University; Dr. Robert P. Lowndes, University of London; and Professor Soon Ng, University of Malaya.

RICHARD C. LORD

UPWARD BOUND

Upward Bound (the former Science Day Camp) concluded its third full year of operation with 74 boys enrolled. All but six of the boys are from Cambridge; the others are from Boston. For eight weeks in the summer of 1967 the boys worked on projects directed by undergraduate and graduate students with the support and consultation of many members of the Faculty. To date some 120 faculty members have participated in this project along with 40 tutors annually. From early October through May the Upward Bound students continued their project work with the M.I.T. students every Saturday. At the invitation of Wellesley College, 15 boys spent every Saturday from January to May with some Wellesley faculty and students in an enrichment program including biology, English, current events, and operation of the Wellesley College radio station.

The faculty-student committee which sets policy for this project spent the winter and spring overseeing a restructuring of the project to include in the offerings academic work designed to support the boys in their high school studies. As the boys have matured in age, their potential for college study is developing and their motivation for post-high school education has grown. Of the original 32 boys from the summer of 1965, some 25 are still in the project and are in the 11th grade. The remaining students concluded in June of 1968 their eighth and ninth grade years.

The Federal funding of this project (80 per cent of the total for 60 poverty-eligible boys) has been increased for the year starting July 1, 1968, to $84,000. M.I.T. seeks support for the 15 authorized boys who do not meet OEO (Office of Economic Opportunity) poverty criteria.

LOUIS MENAND III
URBAN COORDINATING GROUP

The Urban Coordinating Group (U.C.G.) was created during the current year, with the Provost as Chairman, to coordinate the activities of the various individuals, departments, and laboratories at the Institute, oriented to action, teaching, and research on urban problems, and to stimulate those interdisciplinary activities which have as their objective the building up of the Institute's ability to respond on a meaningful basis to the broad, complex problems of the urban area. The membership of the Committee expanded and contracted according to need. However, Deans Lawrence B. Anderson, Gordon S. Brown, and William F. Pounds; Professors John F. Collins, Richard L. deNeufville, Leonard J. Fein, Bernard J. Frieden, Mason Haile, Donlyn Lyndon, Charles L. Miller, Ithiel D. Pool, Lloyd Rodwin, Walter A. Rosenblith, and Carroll L. Wilson; Dr. James B. Hartgering, Frank S. Jones, and Constantine B. Simonides served as a core group.

A first priority of business of the U.C.G. was to survey all of the departments and laboratories at the Institute to provide an answer to the question, "Where are we?" with regard to our present urban commitments. This led to a conference in December, 1967, and the compiling of a "Compendium of Departmental and Interdepartmental Activities in Urban Affairs," which demonstrated a gratifying diversity and intensity of involvement on the part of faculty and staff. The compendium has served as a very useful document for planning and operational purposes.

The agenda for the M.I.T. Urban Affairs Conference held on December 15 and 16 included the following:

"Policy Issues and Research Opportunities: The Model Cities Program." Chairman: Professors Frieden and Jerome Rothenberg

"Race and Poverty." Chairman: Professor Fein

"Information Systems." Chairman: Professor C. L. Miller

"Transportation." Chairman: Professor Marvin L. Manheim

"Education." Chairman: Professor Leon Trilling

"Urban Design." Chairman: Professor Kevin A. Lynch

"Developing Areas." Chairman: Professor Rodwin

"Education for Urban Affairs at M.I.T." Chairman: Professor Rosenblith

With the conference and the compendium as starting points, the U.C.G. met weekly to deal with specific issues of coordination and to define and stimulate activities in the urban area. A great deal of thought and effort went into the creation of a Summer Studies Program, oriented to urban problems, under the leadership, successively, of Professors Lyndon, C. Wilson, and Rosenblith. With partial funding from the Department of Housing and Urban Development, a group of approximately
20 participants from various M.I.T. schools and departments and from outside agencies in the public and private sectors met for a week in mid-June at Woods Hole, Massachusetts, to discuss ways in which advanced technology could be matched to urban needs. This group had as its director Professor Haire of the Sloan School of Management.

A smaller group led by Professor David G. Wilson of the Department of Mechanical Engineering began intensive discussion of the collection, reclamation, and disposal of urban solid wastes. The objective was to discover possibilities of combining the best components into some overall plan that would be feasible from an engineering standpoint, attractive economically, and promise soundness from a management standpoint.

The study group in urban information systems, with Professor de Neufville of the Department of Civil Engineering and Visiting Professor O. Eugene Dial of the Department of Political Science as co-directors, provided a framework whereby all of the various groups at M.I.T. interested in urban information systems could explore their individual and unique approaches to that problem and begin to synthesize these approaches on several concrete and timely concerns of urban managers in the Boston area.

As a final order of business the U.C.G., with Professors Rodwin and Frieden spearheading the effort, promoted a weekly lecture-luncheon series to which outside speakers and members of the M.I.T. community were invited. Topics for the spring series included: Urban Development Strategies Developed by the Kerner Commission; Monitoring the Roxbury Riots of June, 1967; Problems and Strategies of the Boston Redevelopment Authority; Negro Opinion on Racial Issues; The Automobile and the City; and Social and Community Problems of a Housing Project in St. Louis.

FRANK S. JONES

URBAN SYSTEMS LABORATORY

BACKGROUND

The Urban Systems Laboratory (U.S.L.) was established early in 1968 as a new interdepartmental and multidisciplinary activity to mobilize Institute-wide resources in the area of urban systems. U.S.L. is an outgrowth of the recommendations and proposals of the Ad Hoc Faculty Committee on Urban Affairs to President Howard W. Johnson. Support to initiate and organize the Laboratory was provided by a grant from the
Ford Foundation for new efforts in the field of urban affairs. The Institute is making a major commitment to urban affairs, and U.S.L. is to play a key role in carrying out the commitment.

In the extensive deliberations of the Ad Hoc Committee, the goal was to identify special strengths of the Institute which would be most responsive to the special characteristics of urban problems. The conclusions that led to the creation of U.S.L. are best summarized by the following quote from the report of the Committee: "The Institute has pioneered in the fields of operations research, information sciences, computer technology, and systems development. Strengths, resources, and interests in systems research and computer methods of problem solving exist in significant quality and quantity throughout the Institute. Extensive activity in systems analysis and information systems is under way in the Schools of Engineering, Management, Humanities and Social Science, and Architecture and Planning. The powerful problem-solving capabilities represented by these resources offer one of the Institute's greatest potentials for making significant contributions to the formulation and solution of the complex problems of the city."

The problems faced by U.S.L., the problems of the city and urban living, are the broadest and most complex systems problems ever faced by the Institute. The sense of urgency associated with many of these problems requires attention to short-term and very practical considerations. At the same time, few, if any of the problems of the city can be solved by quick and simple solutions. Accordingly, the commitment of the Institute is a long-term one, and work of U.S.L. will go on for several decades or more.

During the first six months of U.S.L., the emphasis has been on careful planning and basic organization to insure a solid foundation upon which to build. With such an important and long-range commitment, a good start is essential to future success. While the Institute has had considerable experience in organizing interdepartmental and interdisciplinary research and project laboratories in engineering and applied science, U.S.L. is the first one to combine architecture, planning, management, and the social sciences as well as engineering on a major scale. Accordingly, U.S.L. is a new experience for the Institute, requiring a considerable amount of bold experimentation.

This report describes the progress made during the first few months of the life of the Laboratory and identifies some of the initial activities associated with or initiated by U.S.L. The report was compiled by our Executive Director, Frank S. Jones, and makes extensive use of the reports prepared by the Associate Directors.
URBAN SYSTEMS LABORATORY

SCOPE

The Urban Systems Laboratory is not a physical laboratory or a separate division of the Institute. Basically, U.S.L. is the community of people of the Institute who are concerned with and active in the field of urban systems. It is an open community, open to all faculty, staff members, and students who find that they can be more effective in the field of urban systems by being active members of the community. Just as in the case of the city, the citizens of U.S.L., should have a voice in what U.S.L. should be, what it should do, and how it should operate and function. The initial participants and potential participants have many divergent interests, skills, priorities, and attitudes. Many will be interacting with each other for the first time, and many will be working on urban problems for the first time. Accordingly, during the early days of U.S.L. we must be very flexible with regard to scope.

While the future scope of U.S.L. is up to the community, for reasons described above, a first approximation is useful. The scope of urban systems is defined initially as the advancement and utilization of the methods of systems analysis, systems engineering, information systems, and related advanced capabilities and technologies applied to the planning, design, construction, and management of the facilities and services required for urban living; including transportation, education, communications, environmental control, housing, health, and others. While most participants will tend to work directly within this defined scope, some will be working one or two steps removed from this concept. U.S.L. will be very broadly defined in scope, but it will not necessarily encompass all of the urban-related activities at the Institute. Many organized and individual activities will be conducted independently of U.S.L.

OBJECTIVES

The basic objectives of the Laboratory are:
1. To develop an environment, framework, and mechanism for helping the individual faculty member and his students pursue their interests in urban research;
2. To strengthen the urban system research efforts and activities of the participating departments and schools, building upon ongoing activities;
3. To facilitate a convergence of individual, group, and departmental interests in urban systems through coordination and support of joint and interdisciplinary efforts;
4. To provide special research resources, capabilities, and services that will assist individuals and groups active in urban systems research, such as computer and information resources;

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5. To promote the development of linkages and interactions with urban action organizations active in applying the results of urban systems research to urban practice. The successful achievement of these objectives will mean a rapid buildup in the Institute's ability to undertake large-scale and mission-oriented urban systems research efforts and projects.

ORGANIZATION AND ORGANIZATIONAL STRUCTURE

The concept of U.S.L. as a community means that people will be the most important resource of this Laboratory. To be sure, the effectiveness of these people can be enhanced greatly by computers and various other tools that are a part of our collective trade. Nevertheless, the number of people, their diversity and quality, and the organizational environment in which these people work will be the prime determinant of whether U.S.L. achieves those quantitative and qualitative goals which have been established by the steering committee.

In this regard, we should like to make a comment about our Laboratory in particular and university laboratories in general. Many technology-oriented companies are in the process of doing precisely what the Institute is doing: creating a mechanism whereby those skills and assets acquired working on the problems of defense and space can be transferred to the problems of the cities. The essential quality which will distinguish our Laboratory, and a potential distinguishing feature of any university laboratory, will be the students. They, in all their extraordinary diversity and energetic dedication, represent an important source of creative new thought, and in their maturity will represent a potential for innovative leadership.

With the importance of students to our effort and with the comprehensive and complex nature of the problem with which we are coping, we are particularly fortunate to have six Associate Directors who represent the focal departments for urban interest within the Schools of Architecture and Planning, Engineering, Humanities and Social Science, and the Sloan School of Management. These Associate Directors and their departmental affiliations are:

School of Architecture and Planning — Professor Donlyn Lyndon, Architecture; Professor Aaron Fleisher, City and Regional Planning.
School of Engineering — Professor Richard L. de Neufville, Civil Engineering.
School of Humanities and Social Science — Professor Jerome Rothenberg, Economics; Professor Ithiel D. Pool, Political Science.
Sloan School of Management — Professor Mason Haire.
The reports of the Associate Directors follow in short order. However, in addition to the above, 110 members of the Institute Faculty and staff have become affiliated with U.S.L. Several times this number will become affiliated in the fall when affiliation is opened to graduate and undergraduate students.

It is helpful to hear how the Associate Directors view the activities of U.S.L. from the focal point of their departments.

Professor Fleisher of the Department of City and Regional Planning notes: "The creation of the Urban Systems Laboratory was most timely. It made it possible for the Department of City and Regional Planning to pursue more rigorously and much more readily the program in the development of research and teaching that it had set for itself. The resources allocated through U.S.L. are being applied for these purposes:

1. The development of DISCOURSE. DISCOURSE is an extensive experiment in the application of the computer to the problems in large-scale design that occur in the building and rebuilding of cities. It is, in effect, an information and manipulation system that widens and amplifies the capabilities of city designers. We are at work now on DISCOURSE 2, enlarging its data structure, increasing its repertory of manipulations, and adding to it graphics as input and output.

2. The synthesis of an urban data system. Our computer system for the storage, retrieval and sorting of data has been operating for two years. It has proved very useful in teaching and research and is being redone and augmented now to take advantage of our experience and the capabilities of the new hardware at the Institute. In addition to its routine use in teaching and research, we regard it also as a context for experiments in the synthesis of an urban data library.

3. Studies in the psychology of perception. Studies in the psychology of perceiving and understanding the urban landscape have been under way in the Department for the past year. We are now able to increase the staff and extend the range and variety of experiments.

4. The Model Cities Program. The Boston Model Cities Program is an important laboratory for teaching and research and an important meeting ground for the Institute and the community. A class in the Model Cities Program was conducted during the past academic term. A small staff of faculty and students is working during this summer with the model cities community in the analysis and development of the model cities program and in preparation of the subjects for the fall term.

These are the direct benefits that have resulted from the establishment of the Urban Systems Laboratory. The indirect effects are no less important. U.S.L. has made it possible to gather resources, existing in
small bits, into amounts that are more efficiently usable. The financing of graphics hardware will prove one such case. It also provides a source of energy and initiative for the formulation of research proposals."

In contrast to the Department of City and Regional Planning, in which all efforts are devoted to the city, the Department of Economics has had relatively little activity devoted to the city. Professor Rothenberg comments: "The most important activity of the Urban Systems Laboratory in its initial stage as it relates to the Department of Economics has been to help stimulate, focus, and coordinate research plans in urban systems. The urban setting has only recently become of interest to economists, and even so has not yet caught the imagination of many of the most powerful mainstream practitioners. A major early task of the U.S.L. has been to spread information among economists about the substantive challenges that are available in the field and in the research work already going on, and the identity of those already engaged in this work. A consequence of this activity has been a notable increase in faculty interaction on urban matters and in student dissertation interest. Some of this aroused attention is taking the form of planning for future research that will come within the purview of the U.S.L. for financing and/or general participation.

"Research now in progress or about to begin also has been influenced by U.S.L. either in its conception, in its scope, or in its very existence. A project by Professor Matthew D. Edel, 'Economics of Community Action,' owes its existence to U.S.L. encouragement and resources. This project will consider the feasibility of economic development of urban neighborhoods by means of self-help institutions. Various models of development will be used in making the analysis.

"An economic study of Negro migration by A. Bradley Askin is being supported by U.S.L. A study of the impact of local government on the location of economic activities within the metropolitan area is being carried out by Professor Rothenberg. The Department of Economics is also involved in the interdisciplinary study on the possibilities for development of the Boston Harbor, directed by Stanley M. Jacks and Professor Kevin A. Lynch. Another current U.S.L.-affiliated project with important participation from the Department of Economics is an Economic Development Administration-sponsored study of the public policy strategies to increase ghetto-resident employment.

"In addition to research already being carried out, there are a number of projects being planned for the next year which derive in part or whole from the urban emphasis imparted by U.S.L. and/or the availability of some U.S.L. support. Among these are a study by Professor Michael J.
Piore (in collaboration with Professor John T. Dunlop and Peter B. Doeringer of Harvard University) which will experiment with techniques for evaluating manpower programs designed to aid the urban poor; a study by Professor Edwin Kuh on the financial aspects of Federal-state-local government relations; an attempt by Professor Duncan K. Foley to extend the powerful new theoretical models of competitive general equilibrium in market systems to embrace the spatial distribution of economic activities, which is the foundation of the economic analysis of urban areas; a study by Professor Rothenberg of techniques for evaluating supply of labor in smaller Soviet cities; and a study by Professor John R. Harris on urban growth in Kenya. This research menu suggests a widening and deepening of interest by professional economists in urban systems, a process which may well become self-reinforcing. Faculty interest is augmented by a substantial increase of student interest in writing doctoral and Master's dissertations in the same area.

"In addition to research, the Department of Economics has recently increased its teaching program substantially in the urban systems area. A new systematic three-term graduate subject in urban economics has been introduced, as well as an undergraduate subject in urban economics. Besides these, a graduate seminar is being considered which will integrate public policy-oriented issues within a single setting. Urban problems will be heavily represented.

"A good start has been made to bring the discipline and manpower of mainstream economics toward the resolution of urgent current urban problems. The work of U.S.L. can well consolidate and amplify this progress."

Professor Pool chronicles the growth of professional interest in urban affairs in the Department of Political Science as follows: "The creation of the Urban Systems Laboratory has coincided with a trend of growing strength in this Department in urban research and instruction. Three years ago the faculty in the urban field was two out of 30. Today it is 11 out of 40. This is not to suggest, however, that those faculty members counted in the urban field are not in many cases instructing and conducting research in other fields as well. During the same period our subject offerings in the urban field have increased from one to seven. Our urban research capability is therefore reaching a scale that makes an institution such as the Urban Systems Laboratory vitally necessary to the realization of our potential in this field. The published objectives of the Laboratory are in complete harmony with our view of the genus and dimension of the support our faculty will require in order to participate in large-scale urban systems research by 1970."
"A survey of departmental faculty conducted in April of this year yielded a total of nine faculty and five projects to be associated with the Urban Systems Laboratory. Examples of such activities include the following:

1. Model Cities Program. Support provided by the Laboratory made it possible to plan substantial assistance to the Boston Model Neighborhood Board and Administration. This assistance has already taken the form of training for field surveyors and consultation with the board and administration. Assistance projections for the near future include the installation of a remote teletype in the board and administration headquarters; a generous allowance of computer time and disc storage; a generalized program, ADMINS, for data file management and analysis; and training of personnel needed to operate in the system.

2. Summer Studies Program. The Summer Studies Program, sponsored by U.S.L., has involved five members of this Department in the Group-II Project on Urban Information Systems. A subunit of this group, with two departmental faculty participating, has assumed the task of providing tangible, short-run (as well as long-run) assistance to the Boston Model Neighborhood Program. In the short run, this assistance includes training; data selection, transmission, and analysis; the design of a system of family life centers; and an information system appropriate for incremental implementation.

3. Seminar Series on Urban Technology. Various members of the Department, and particularly those associated with the Laboratory, have attended the Saturday Seminar Series on Urban Technology arranged by the Laboratory."

The Alfred P. Sloan School of Management has focused the efforts of much of its faculty on the problems of matching technology, as Professor Haire indicates: "Within the Sloan School, the following activities can be identified:

1. A faculty committee canvassed the faculty to identify ongoing research and research interests relevant to urban systems. An internal catalogue has been begun, and the group prepared and distributed to the Faculty a position paper (tentative) for the School's role in urban problems.

2. Under U.S.L. sponsorship and with the guidance of the Institute Urban Coordinating Group, the School took responsibility for conducting a series of seminars this spring. The aims were to explore the problems of matching technology to urban problems, to provide an interdisciplinary forum, and to stimulate research interest. More than 40
M.I.T. faculty from seven departments attended, and Westinghouse, TRW, and Lockheed sent representatives to make presentations.  

3. Within the framework of the proposal made by the U.S.L. to HUD (Department of Housing and Urban Development), the School has taken the major responsibility in framing the summer study on Matching Technology to Urban Needs. Ten M.I.T. faculty from five departments will attend with five or six outsiders — from the Urban Institute, the National League of Cities, the Office of the Mayor of New York, and the like.  

4. A series of seed research projects have begun which will have major follow-on possibilities. (a) Professor Jay W. Forrester is building a computerized industrial dynamics simulation model of processes of stagnation in the city. (b) Professor David A. Kolb is preparing a proposal on a study of the relationship between helper and helped with reference to the city. (c) Stanley M. Jacks and others have contracted with the Harbor Islands Commission to do a preliminary study of possible urban development in the Columbia Point area."

Professor Lyndon indicates the beginning involvements with urban systems in the Department of Architecture as follows: "Urban Systems Laboratory work in the Department of Architecture this year has been principally preparatory.  

"At the end of the year, members of the Department were ready to begin work on three projects with U.S.L. support: Communication in Urban Problem Solving, Computer-Aided Urban Design, and Environmental Planning for v/STOL (Vertical Short Takeoff and Landing) air transportation. The first is a continuation of work that Stuart M. Silverstone initiated during the spring term in the Department of Architecture and will be extended to examine many phases of U.S.L. work. The second will extend the range of considerations presently being explored under Nicholas P. Negroponte and Leon B. Groisser with URBAN 5 into a new order of designer-machine interaction. This forms a part of a broad program in computer-aided design that extends from work on space allocation systems under a grant from the National Science Foundation to the work in DISCOURSE being carried out by the Department of City and Regional Planning.  

"Professor William L. Porter, who served during the spring as Acting Associate Director for Architecture, has been working with DISCOURSE and during the coming year will be responsible, with Professor John R. Myer, for an expanded graduate program in urban design. He will, as well, direct a program of curriculum development research with partial support from the Urban Systems Laboratory."
"Work on V/STOL transportation will be continued in collaboration with the Department of Aeronautics and Astronautics. Professor Edward B. Allen will direct studies of environmental factors related to the development of interchange facilities required to join V/STOL transportation with other forms of urban transit.

"The intricate linkages between transportation and urban design have been the subject of continuing exploration in U.S.L., and Professor Myer will work with an interdisciplinary group to explore means for bringing consideration of environmental quality into a more effective role in transportation planning procedure.

"The development of more explicit procedures for the exchange of information during the design process has been the subject of a design information study group in the Department of Architecture and was the principal subject of a Design Methods Group Conference held this spring in joint sponsorship with the Department of Civil Engineering and the Harvard Graduate School of Design. Initial studies are being made regarding the possibilities for an environmental simulation workshop and laboratory.

"In addition, members of the Department contributed substantially to planning for the U.S.L. Summer Studies Program, supported by HUD."

Finally, Professor de Neufville of the School of Engineering comments on the activities of that School: "The initial efforts in the School of Engineering have been focused on the development of a creative educational environment that opens up opportunities for students and faculty to participate in the solution of urban problems and that stimulates them to do so. The main thrust of the activities to date has therefore been, first, to create a community of interest in urban systems out of the existing disjointed involvements, and second, to establish working relationships with action-oriented urban managers through which M.I.T. can participate in the solution of real problems.

"As a result, engineering students have already participated in several important urban design projects. The subject, Interdisciplinary Systems, evolved a development plan for Boston Harbor which will be extended under contract with the Massachusetts Port Authority and the Massachusetts Area Planning Council on the design of an airport for Boston Harbor; graduate students worked with the New York City Bureau of the Budget on an analysis of long-range municipal water supply problems. Mechanical engineering students in Professor David G. Wilson's project subject evolved a design for metropolitan waste disposal.

"A graduate program of study in urban systems has been formulated
by the Department of Civil Engineering to combine the formal student activities. This curriculum was approved by the HUD, which then also awarded an Urban Studies Fellowship to Miss Karla S. Hurst.

"Further research and educational opportunities are now being developed for the 1968-69 academic year. The Departments of Civil Engineering and Architecture are, under the leadership of Professor Charles L. Miller, arranging for design assistance to the Boston Redevelopment Authority on the creation of a new community in the harbor. Similar technical assistance is being provided by Professor T. William Lambe of the Department of Civil Engineering to the Massachusetts Bay Transit Authority. Discussions are likewise being held with Boston's Model City Administration on the adaptation of information systems to their needs.

"A grant for a summer study on urban information systems has been awarded to the Urban Systems Laboratory by HUD and is codirected by Professors de Neufville and O. Eugene Dial. A parallel study of the waste disposal problem has likewise been approved and will be conducted by Professor Wilson.

"The development of a community of interest is being fostered through research initiation projects in areas such as building systems and urban hydrology, where longer-term relationships can be expected with urban managers. Seminars with major developers and users of urban systems — the Boston Redevelopment Authority, Westinghouse, TRW, Lockheed, Building Systems Design, and the Office of the Mayor of New York — were held on the introduction and application of technology to the city.

"These developments are opening a range of opportunities for interdisciplinary work. In the Department of Civil Engineering, for example, Professor William A. Litle is working on low-cost housing in cooperation with the Harvard-M.I.T. Joint Center for Urban Studies, and Professor Kenneth F. Reinschmidt is similarly involved in a project for HUD. The Departments of Architecture and Civil Engineering have proposed to investigate the possibilities of interdisciplinary design teams for urban highways and transportation links and in this vein have sponsored the Design Methods Group Conference held at M.I.T. in June."

**URBAN RELATIONSHIPS**

As has been mentioned previously, much of the initial conceptual thinking about the U.S.L. was influenced by our experience with defense and space problem solving. In those experiences it was quite easy to determine who was the client for the Institute's services. A favorite question
among those currently interested in urban affairs is, "Who is the client?"
Put another way, if U.S.L. conceives of itself as a problem solver, who
has the problem and will he implement solutions?

It has been mentioned in the individual reports that considerable ef-
forts have been expended in creating successful institutional relationships
between the "problem havers" and the "problem solvers." Institutional is
a key word in this context, because while faculty members of several
departments have had relationships with urban actors over many years,
there have been few, if any, relationships — transportation is a notable
exception — in which there has been collaboration between a number
of departments at M.I.T. with an equally broad cross section of an urban
action agency. So far extensive relationships have been developed by
U.S.L. groups working in collaboration with the Boston Redevelopment
Authority, the Boston Model Cities Board and Administration, and the
Massachusetts Harbor Commission.

SPACE AND FACILITIES
Most of the research work associated with U.S.L. will be carried out
in departmental settings to insure close interaction with the educational
program and participation by students. The extensive research facilities
and laboratories of the participating departments will be utilized, as
well as those of other interdepartmental laboratories. Indeed, bringing the
many existing research facilities throughout the Institute to bear on
urban problems is a basic objective of U.S.L. The mobilization, adap-
tion, and focus of established capabilities is sought rather than the
addition of still another laboratory unit.

While the work of U.S.L. will be pursued throughout the campus, a
modest central complex of office and workshop space has been arranged
through a federation of U.S.L. with the Center for Advanced Engineer-
ing Study (C.A.E.S.). The central complex will provide a unifying
home for those concerned with the management, administration, and
leadership of U.S.L. and participants in interdepartmental projects
and activities. On a temporary basis, U.S.L.'s central complex will be
located on the fifth floor of the new C.A.E.S. building to facilitate close
interaction between U.S.L. and the C.A.E.S. on a joint program of mid-
career development in urban systems to be initiated next year.

EXPERIMENTAL COMPUTER RESOURCES
The computer is basic to urban systems research and is a common
denominator for the many diverse activities of the Laboratory. Com-
puter-based urban systems research is already under way in all depart-
ments and groups federated with U.S.L. and is the basis for many of our strengths and experiences. Access to an experimentally oriented computer is essential to new research in urban information systems, urban simulation, and urban design as planned by many groups associated with U.S.L. We have the extensive computer software developments represented by DISCOURSE (Architecture and City Planning), ADMINS (Political Science), DYNAMO (Management), AED (Electronic Systems Laboratory), and ICES (Civil Engineering) to build upon.

To provide the experimental computer resources required by the Laboratory, arrangements have been made for the installation of an IBM System/360, Model 67 during the summer of 1968 in the new Information Processing Services Center building. The systems management and systems engineering responsibility for the new computer will be provided by the newly formed U.S.L. computer systems group for the coming year. The group will be headed by Professor Jay R. Walton, who will serve as Associate Director for Computer Systems of U.S.L. Miss M. Elizabeth Schumacher is serving as Project Manager for preinstallation planning and for initial operation. The machine will be operated in cooperation with the M.I.T. Lincoln Laboratory and the Cambridge Scientific Center. Machine operations and support services will be provided by the Information Processing Services Center, and the machine will also be used for experimental work for a computer network at the Institute.

Remote consoles will be provided for urban systems research groups in the participating departments and in the U.S.L. central complex, to provide on-line and interactive capability. A computer graphics laboratory will be developed in the central complex, initially with the ARDS-type storage tube graphical terminals on-line with the 360/67. The 1130 computers in the Sloan School and the Civil Engineering Systems Laboratory (CESL) will also be linked to the 360/67 for remote I/O experiments in urban problem solving.

U.S.L. is indeed fortunate to have a very powerful experimental computer capability to work with in the coming year. The computer will be a significant focal point for our interdepartmental and interdisciplinary activities and will accelerate our research progress. The facility has been made possible by support allocated to U.S.L. from a grant to the Institute by the IBM Corporation.

PERSONNEL

With the highly decentralized approach being taken during the initial stage of U.S.L., the key personnel are the Associate Directors and the
faculty and staff within the participating academic departments. All appointments are made and staff hired through the departments to insure a close coupling with the educational programs and with students. We have avoided a large central staff and administrative structure, relying on a few members of the staff of the Department of Civil Engineering for the Office of the Director.

Frank S. Jones, Senior Lecturer, joined the Institute in February as Assistant Director of U.S.L. and provided outstanding assistance to me in launching the new Laboratory. In recognition of his increasing senior management role in the operations of U.S.L., he will become Executive Director as of July 1, 1968. In addition to the complex task of bringing in the 360/67 computer, M. Elizabeth Schumacker, Lecturer, has served as Special Assistant to the Director, providing invaluable assistance on numerous special assignments. Henry W. Bruck, Lecturer, has also joined the staff of the Director and will be responsible for planning and coordinating many of the interdisciplinary activities of the Laboratory, particularly the interactions between the social sciences and engineering.

**SUMMARY**

The progress of U.S.L. during its first six months can be summarized as follows: (1) the Lab is organized and in operation; (2) a series of research initiation and multidisciplinary projects are under way in all participating departments; (3) linkages and interactions have been established with urban action agencies in the local community; (4) space has been obtained for a central complex and U.S.L. headquarters; (5) arrangements have been made for a large-scale experimental computer resource; and (6) a base and framework for greatly expanded activities in urban systems at the Institute has been established.

Interest in U.S.L. has been extremely high, both internally and externally. The student response has been particularly gratifying and reflects a serious and dedicated interest in becoming involved in constructive efforts to solve urban problems. Students turning to U.S.L. are particularly anxious to relate their academic study programs to real problems and issues, and they look to U.S.L. for a coupling with action in the cities. Faculty interest in participation far exceeds U.S.L. ability to provide financial resources for their proposed research activities. Indeed, inadequate financial resources is the overwhelming problem faced by U.S.L. as we look ahead. We will not be able to be responsive to the faculty and student interests already generated due to lack of funds. For the coming year, the problem is extremely serious, but in the long run we hope the resources will be found.
Finally, those of us associated with launching the new laboratory wish to acknowledge the exceptional interest shown and assistance provided by the administration of the Institute. The President, the Provost, and the administrative officers have viewed U.S.L. as a serious and significant commitment on the part of the Institute to the great challenge of our times and the years ahead. Their advice and help have been a significant factor in the progress to date.

CHARLES L. MILLER

WELLESLEY-M.I.T. UNDERGRADUATE EXCHANGE PROGRAM

President Ruth M. Adams of Wellesley College and President Howard W. Johnson announced this new program in a news conference on May 17, 1967. The purpose of the exchange program is to extend the diversity of educational experiences now available in the curricula and the environments of both institutions to the students and faculty of each. The two institutions proposed to conduct cross-registration of undergraduate students and to develop experimental courses and curricula based on the experience gained through cross-registration. A student-faculty committee was appointed to make plans for the program, which was to start formally in September, 1968. The M.I.T. half of the Joint Committee consisted of Dean Robert A. Alberty (co-chairman with Dean Virginia Onderdonk of Wellesley), Professors Stanford O. Anderson, Richard M. Douglas, Walter A. Rosenblith, Dr. Benson R. Snyder, Dean Emily L. Wick, and student members Karla S. Hurst, Mark Spitzer, and Alan S. Willsky.

Student interest was so great that a number of students were permitted to cross-register on an ad hoc basis before the official start of the program. During the fall term of 1967-1968, four pioneering students (two from each institution) cross-registered, making their own transportation arrangements. During the spring term, a total of 48 students was permitted to cross-register on the same basis: 25 Wellesley College students from 11 departments took 15 different subjects at M.I.T. in nine departments; 23 M.I.T. students from 11 departments took 16 courses at Wellesley in ten departments.

This preliminary experience has been useful and encouraging. The students, on the whole, have done well in the courses they selected and have accomplished this in spite of some problems in reconciling quite different schedules and arranging for transportation and meals. The stu-
Students have also provided valuable feedback to the Joint Committee as it made final plans for the program in the fall.

A questionnaire on the program was distributed to students at both institutions in November, 1967. Of the 1,600 questionnaires returned, about 70 per cent favored the cross-registration program (the Wellesley response was about 75 per cent favorable and the M.I.T. response was about 65 per cent favorable).

In a further indication of interest and support, the two student governments arranged Exchange Days on March 11 and 13, 1968. On the first day about 800 M.I.T. students were hosted on the Wellesley campus, and on the second day some 300 Wellesley College students visited M.I.T. The students got a first-hand acquaintance with the other campus through visiting classes, talking with various faculty members, participating in discussions, and visiting various living groups on both campuses.

A number of feedback interviews have been held between members of the Joint Committee and groups of students cross-registered during the spring term of 1968. These have provided useful insight into effectiveness of the program and the students' reactions to it.

One M.I.T. faculty member commented on the program:

It is working. Each student said emphatically that he or she is in the exchange without regret and feels "everyone should try it once." They unanimously respond to the change of tone and environment, and seem to flourish in the experience of tourists visiting a strange and wonderful land. The tissue of motives is complex. But Wellesley girls keep talking about the "Convent" they want to escape, in order to return to the reality of a city and the intensity of a university. M.I.T. students in turn talk about leaving the "Factory" of M.I.T. for the benign, serene, pastoral openness of Wellesley. . . . Yet students from each campus report a new appreciation, or at least a new understanding, of their own institution. . . . For my own part, I have been converted from something of a skeptic (a year ago) to a real enthusiast. The program under test is surpassing expectations, and is providing a very significant addition to the education — formal and otherwise — of all who are in it, so far as I can tell.

An M.I.T. student commented as follows about his experience in taking two courses at Wellesley:

I enjoyed the program very much. I was enrolled in two subjects. . . . The instructors . . . were absolutely topnotch. . . . It was a pleasure attending a campus that is beautiful and countrylike. I even did a bit of ice skating on the lake there during the winter. . . . I would suggest that the exchange program be continued and expanded.

In September, 1968, there will be about 80 M.I.T. students taking subjects at Wellesley and about 80 Wellesley students taking subjects at M.I.T. M.I.T. students have received permission to take subjects in 21
Wellesley departments. The largest number are in Astronomy, Chinese, History, English, and Sociology. The M.I.T. Courses with the largest number of Wellesley students are Architecture, City and Regional Planning, and Humanities.

ROBERT A. ALBERTY
On June 30, 1967, Dean Harold L. Hazen retired at the end of a 15-year tenure as Dean of the Graduate School. Under his leadership the Graduate School enjoyed an unprecedented period of growth in size and quality of educational programs. On July 1, 1967, Professor Irwin W. Sizer, Head of the Department of Biology, became Dean of the Graduate School. In the first year of his tenure the Graduate School has continued to develop along many lines. At the same time, certain problems have arisen on the national scene which require extensive attention at all levels. The developments which have occurred in various aspects of graduate education are considered in the following sections.

GROWTH IN NUMBER OF GRADUATE STUDENTS

The Graduate School has continued to grow along a fairly smooth curve since the end of World War II (see figure entitled Regular Graduate Students, 1946-1967). In the period from 1954 to 1964 in particular, the increase in growth was at the rate of about 5 per cent per year. After careful consideration of all factors, and especially the need to keep the graduate school in balance with the undergraduate school, the administration decided that a more appropriate rate of growth for the graduate school would be 3 per cent per year. Rigid quotas were set up for each department to keep growth within these limits. Exceptions were made, however, for rapidly developing programs as well as new departments. For the fall of 1967, the quota set for regular graduate students was 3,342; the actual number of students registered was 3,344. In addition to the regular students, there were 529 special graduate students who were non-degree candidates taking one or two subjects per term.
The problems posed by Selective Service together with the major curtailment of Federal fellowships caused the administration and the Committee on Graduate School Policy to set the quota for September, 1968, at the same level as for 1967. However, due to the uncertainties of graduate enrollment, it was decided to apply quotas with considerable flexibility during the coming year. Preliminary estimates for enrollment in September, 1968, suggest that it will decrease slightly (2 per cent) compared with the previous year. It is expected that when the national emergency is over, the graduate enrollment will increase at a rate of about 3 per cent per year once more, in order for it to correspond with other plans for growth at M.I.T.

FELLOWSHIPS, SCHOLARSHIPS, AND ASSISTANTSHIPS

The support of graduate students by fellowships, scholarships, and assistantships has continued at a very high level during the past year. Some 91 per cent of the graduate students were aided by such means. Most students (about 48 per cent) were teaching or research assistants, some (about 23 per cent) were awarded Federal fellowships, and still others received aid from other sources, including foreign governments, relatives and industry. Most of these students received financial aid sufficient to cover both living expenses and tuition. A small percentage of students were awarded partial financial assistance and quite a large number of graduate students received loans from the Student Aid Fund. A summary of the major financial support for graduate students during the past year is presented in the accompanying tables (see Tables I, IV, and V).

The outlook for the coming year is a discouraging one with reference to financial aid for graduate students. There are many reasons for this reduced assistance program:

1. Beginning in the fall of 1968, M.I.T.'s tuition will be increased. Added to this tuition increase will be a substantial medical fee.
2. There has been a curtailment of national fellowships for graduate students at M.I.T. for 1968-69. This decrease applies especially to fellowships from the National Aeronautics and Space Administration, the Atomic Energy Commission, and the Woodrow Wilson Foundation. Still unaffected are fellowships and traineeships from the National Science Foundation and the Public Health Service (NIH), but anticipated budgetary cuts in Washington will certainly affect these fellowships as well.
3. Since Research Assistants receive stipends from research grants derived primarily from Federal agencies, any reduction in Federal funds for research will inevitably have a deleterious effect upon the number of research assistantships available. Even if research funds at M.I.T. are
Graduate School

not curtailed, there will be fewer research assistantships because of the increased cost to research projects brought about indirectly by increased tuition and fees, as well as the escalated costs of carrying on research. 4. Although the total budgetary allocation for Teaching Assistants has not decreased, there will be fewer in total number because of a decision to use more teaching assistants who are full-time rather than part-time during the coming year.

The full impact of the curtailment of financial support for graduate student education has not yet been felt. Although all areas at M.I.T. will feel the impact in one way or another during the coming year, special problems have already arisen in the fields of management, economics, political science, and physics. Some of these emergency problems have been taken care of by special allocation of funds from the academic budget. In addition, a sum of money for tuition scholarships has been allocated to the Graduate Office to be used in solving emergencies in the field of graduate student aid wherever and whenever they may arise.

Selective Service

The Draft Act of June, 1967, called for the cancellation of draft deferment for all graduate students who entered graduate school after September, 1967, with the exception of those in medical and para-medical fields. During the fall of 1967, President Lyndon Johnson asked a subcommittee of the National Security Council to look into this new Act and make recommendations to decide which graduate fields of study were in the national interest, with the possibility that scientists and engineers be added to the list of those students who would be draft-exempt. During the fall term, the Committee on Graduate School Policy at M.I.T. examined this matter of draft exemption with great care and voted unanimously in favor of the following resolution:

The M.I.T. Faculty recommends that, under Selective Service legislation, all graduate students be treated equally without limitation or preference as to their particular disciplines or fields of study.

After a series of deliberations involving joint meetings between the M.I.T. faculty members and the Committee on Graduate School Policy, the above resolution was adopted by the Faculty with the recommendation that it be transmitted to President Lyndon Johnson and members of the National Security Council.

In February, 1968, General Lewis B. Hershey announced the reaffirmation of the original policy that only medical and para-medical graduate students would be eligible for deferment. Hence all M.I.T. graduate students eventually would become draft eligible.
During the spring term, the Graduate Office organized a series of discussions concerning Selective Service regulations as they related to the graduate and prospective graduate student at M.I.T. Initially an all-Institute convocation was held with the cooperation of Colonel Paul Feeney, Deputy Director of Selective Service in Massachusetts, and other individuals from M.I.T. This was followed by meetings with graduate students and faculty in each department. These meetings were chaired by either the Dean or the Associate Dean of the Graduate School and were very well attended.

After much deliberation, and particularly in view of General Hershey's directive of April 25, 1968, stating, "A full-time graduate student shall not be considered for an occupational deferment because he is engaged in teaching part-time," the Academic Council and the Committee on Graduate School Policy decided that M.I.T. would request occupational deferment for only its full-time Teaching Assistants who are also registered as graduate students. For other students, the Graduate School Office, at the request of the student involved, will present the best case possible based on the importance of the student's progress toward a graduate degree and his other contributions, such as teaching and research. The Graduate Office has been reorganized to take care of all problems relating to Selective Service on an individual basis, taking into account the needs and individual circumstances of each graduate student.

The new Selective Service Act has necessitated the coordination of M.I.T.'s concerns in this area for all its students, staff, and employees. In order to set policy and to coordinate its implementation, the President of M.I.T. has appointed a Committee on Selective Service made up of the following: Associate Dean Sanborn C. Brown of the Graduate School, Chairman; Malcolm G. Kispert, Vice President for Academic Administration; Jack P. Ruina, Vice President for Special Laboratories; Irwin W. Sizer, Dean of the Graduate School (in Dean Brown's absence during 1968-69, Dean Sizer will be Chairman of this committee); Prescott A. Smith, Assistant Secretary of the Faculty; Philip A. Stoddard, Vice President for Operations and Personnel; Kenneth R. Wadleigh, Dean of Student Affairs; and Robert K. Weatherall, Assistant Dean of the Graduate School. This committee will supervise and coordinate the activities of the several Selective Service advisory offices in various parts of the Institute.

Since many students who are admitted to the Graduate School for the pursuit of a particular degree end up studying for a different degree or going on for an advanced degree after they have completed the Master's or Engineer programs, it became necessary to establish a new admis-
GRADUATE SCHOOL

sions policy because of recent Selective Service developments. Beginning in September, 1968, all graduate students will be admitted to the Graduate School, and at the time of registration the student, with his Registration Officer, will determine for what degree he will register. If a student plans ultimately to work toward a doctoral degree but wishes to qualify for a Master's degree along the way, he will be registered for the higher degree. In the term during which he completes requirements for the lower degree, he will be granted it, but he will continue to be registered for the higher degree. In this way a student will continue to be registered in the Graduate School without interruption even though he may qualify for more than one degree.

Since many graduate students and prospective graduate students will be drafted during the coming years, it was necessary for the Committee on Graduate School Policy to establish a policy on the readmission of graduate students who apply after they have performed a tour of duty with the armed forces. The resolution adopted is as follows:

A graduate student in good standing whose education is interrupted for reasons related to Selective Service will be readmitted irrespective of whether he enters the armed forces, or does not serve because of moral or conscientious objection, if he applies for readmission within five years after he leaves M.I.T.

NEW GRADUATE DEGREE PROGRAMS

On May 8, 1968, an agreement was signed by M.I.T. and the Woods Hole Oceanographic Institution for a joint program of graduate education in oceanography. This program will be supervised by a joint committee from the two institutions and will permit a student to pursue subjects and research at both institutions. This program will operate in conformity with the usual requirements of the M.I.T. Graduate School.

A new program in ocean engineering has been approved in the Department of Naval Architecture and Marine Engineering. Students in this program may enroll in subjects and do research at the Woods Hole Oceanographic Institution. The research may be supervised by regular M.I.T. faculty or those who hold joint appointments at the two institutions.

A cooperative program leading to a Bachelor's degree in physics and a Master's degree in nuclear engineering requiring five years of integrated subjects and research was presented to the Committee on Graduate School Policy. In this program, the student spends the major part of the first four years in the Department of Physics. In his senior year, however, he begins to take subjects in nuclear engineering and in his fifth year, his major work and thesis are carried on in the Department of Nuclear Engineering.

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GRADUATE SCHOOL

GRADUATE STUDENT AFFAIRS

GRADUATE STUDENT COUNCIL

The Graduate Student Council is made up of a representative from each department at M.I.T. plus delegates from various living groups. Officers of this Council meet regularly with Associate Dean Robert J. Holden of the Office of Student Affairs. During the last year joint meetings of the Graduate Student Council and the Committee on Graduate School Policy have been set up so that the full membership of the two groups meets each term to discuss problems of mutual interest. In addition, the officers of the Graduate Student Council meet upon occasion with the officers of the Graduate School.

Two representatives of the Graduate Student Council now sit as observers at all meetings, except executive sessions, of the Committee on Graduate School Policy. In addition, agendas and reports of meetings of the Committee on Graduate School Policy and the Graduate Student Council are exchanged by the two groups. By these means, a close working relationship has developed between the Graduate Student Council and the Graduate School. It is expected that during the coming year subcommittees of the Graduate Student Council and of the Committee on Graduate School Policy will be set up to deal with special problems relating to academic matters and student life at M.I.T.

THE NEGRO GRADUATE STUDENT

Since the enrollment of Negro Americans is low at M.I.T., the Committee on Graduate School Policy has devoted considerable time to a discussion of how the number of Negroes can be increased. A special subcommittee was appointed to look into the matter and to formulate recommendations for action. The Graduate Student Council has appointed a similar subcommittee which is cooperating closely with the Faculty on this matter. Since the problem is not peculiar to the Graduate School, it is expected that the problems of the Negro will be approached on a much broader base by several groups of faculty and students. Coordination among these various committees is essential if progress is to be made.

GRADUATE STUDENT HOUSING

The completion of Eastgate, designed primarily for the housing of married graduate students, has made it possible to go on to the next phase of the problem. Under the leadership of the Dean of Student Affairs, a committee including the Dean and Associate Dean of the Graduate
GRADUATE SCHOOL

School has met regularly during the year. Ground rules for graduate housing were established, and after this phase was completed, a new stage of implementation has been initiated under the leadership of the Vice President for Operations and Personnel. During the coming year, specific proposals for graduate student housing will be developed.

LANGUAGE REQUIREMENT FOR THE DOCTORAL DEGREE

During the year the Graduate Office solicited comments concerning the foreign language requirement through a questionnaire from the Faculty. Discussions on this matter were also held by the Graduate Student Council and the Committee on Graduate School Policy. With the assistance of the Department of Modern Languages and Linguistics, it is expected that a new policy on language requirements for the doctoral degree can be evolved during the coming year.

PERSONNEL

During the coming year, Associate Dean Sanborn C. Brown will be on sabbatical leave sponsored by the Guggenheim Foundation. During his absence some of his responsibilities in the Graduate School Office will be assumed by Robert K. Weatherall, who has been appointed Assistant Dean of the Graduate School. Mr. Weatherall will also devote half his time to the Admissions Office, where he will serve as Associate Director of Admissions.

IRWIN W. SIZER

Table I  Summary of Graduate Financial Assistance for 1967-68

<table>
<thead>
<tr>
<th>Total Regular Graduate Students</th>
<th>3344</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal fellowships and traineeships</td>
<td>796 (23%)</td>
</tr>
<tr>
<td>Graduate student staff</td>
<td>1586 (48%)</td>
</tr>
<tr>
<td>Industrial and foundation awards</td>
<td>206 (6%)</td>
</tr>
<tr>
<td>M.I.T. endowed and budgeted funds</td>
<td>53 (2%)</td>
</tr>
<tr>
<td>Students sponsored by external sources</td>
<td>406 (12%)</td>
</tr>
<tr>
<td><strong>Total Awards</strong></td>
<td><strong>3045 (91%)</strong></td>
</tr>
</tbody>
</table>

Table II-A  Graduate School Quotas and First-Term Registration, 1967-1968

<table>
<thead>
<tr>
<th>All Schools</th>
<th>Engineering</th>
<th>Science</th>
<th>Architecture and Planning</th>
<th>Humanities and Social Science</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota</td>
<td>3342</td>
<td>1630</td>
<td>1006</td>
<td>132</td>
<td>274</td>
</tr>
<tr>
<td>Registration</td>
<td>3344</td>
<td>1608</td>
<td>1031</td>
<td>139</td>
<td>259</td>
</tr>
</tbody>
</table>

514
Table II-B  History of Quotas and Registration, All Schools, 1963-1967

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota</td>
<td>2842</td>
<td>2963</td>
<td>3084</td>
<td>3232</td>
<td>3342</td>
</tr>
<tr>
<td>Registration</td>
<td>2804</td>
<td>3087</td>
<td>3196</td>
<td>3198</td>
<td>3344</td>
</tr>
</tbody>
</table>

Table III  Graduate School Statistics, 1967-1968

<table>
<thead>
<tr>
<th>Advanced Degrees Conferred:</th>
<th>M. Arch. and M.C.P.</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, 1967</td>
<td>40</td>
<td>201</td>
<td>25</td>
<td>20</td>
<td>95</td>
<td>381</td>
</tr>
<tr>
<td>February, 1968</td>
<td>4</td>
<td>148</td>
<td>22</td>
<td>21</td>
<td>82</td>
<td>277</td>
</tr>
<tr>
<td>June, 1968</td>
<td>6</td>
<td>332</td>
<td>82</td>
<td>28</td>
<td>105</td>
<td>553</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>681</td>
<td>129</td>
<td>69</td>
<td>282</td>
<td>1211</td>
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</tbody>
</table>

Graduate School Registration*

<table>
<thead>
<tr>
<th></th>
<th>Summer, 1967</th>
<th>Fall, 1967</th>
<th>Spring, 1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Engineering</td>
<td>889</td>
<td>1931</td>
<td>1759</td>
</tr>
<tr>
<td>School of Science</td>
<td>690</td>
<td>1117</td>
<td>1043</td>
</tr>
<tr>
<td>School of Architecture and Planning</td>
<td>51</td>
<td>181</td>
<td>168</td>
</tr>
<tr>
<td>School of Humanities and Social Science</td>
<td>105</td>
<td>300</td>
<td>279</td>
</tr>
<tr>
<td>Alfred P. Sloan School of Management</td>
<td>87</td>
<td>344</td>
<td>316</td>
</tr>
<tr>
<td>Total</td>
<td>1822</td>
<td>3873</td>
<td>3565</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>U.S. and Canadian citizens</th>
<th>Other nationalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Engineering</td>
<td>3148</td>
<td>725</td>
</tr>
<tr>
<td>School of Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Architecture and Planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Humanities and Social Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfred P. Sloan School of Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3873</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Regular Students</th>
<th>Special Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Engineering</td>
<td>3344</td>
<td>529</td>
</tr>
<tr>
<td>School of Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Architecture and Planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Humanities and Social Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfred P. Sloan School of Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3873</td>
<td></td>
</tr>
</tbody>
</table>

*Includes special graduate students

Table IV  Graduate Student Support

The sources of support for most of the 3,344 M.I.T. graduate students in 1967-68 are listed. However, a single table is an incomplete reflection of the total picture, since support constantly shifts and changes throughout the academic year in accordance with changing student status, early termination of degree program, the draft, and so on. To diminish the statistical problem created by this constant change, this table was devised to present a "snapshot," in effect, taken in October, 1967.

Fellowships and Traineeships Awarded by M.I.T.

- National Aeronautics and Space Administration Traineeships 39
- National Defense Education Act Traineeships 131
- National Science Foundation Traineeships 146
- National Institutes of Health and Other Health, Education, and Welfare (HEW) Traineeships 123

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### Table IV (Continued)

<table>
<thead>
<tr>
<th>Fellowships Awarded by Sponsors to M.I.T. Students</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic Energy Commission Fellowships</td>
<td>45</td>
</tr>
<tr>
<td>National Science Foundation Fellowships</td>
<td>230</td>
</tr>
<tr>
<td>National Institutes of Health and Other HEW Fellowships</td>
<td>74</td>
</tr>
<tr>
<td>National Aeronautics and Space Administration</td>
<td>4</td>
</tr>
<tr>
<td>Housing and Urban Development Fellowships</td>
<td>3</td>
</tr>
<tr>
<td>National Defense Foreign Language Fellowships</td>
<td>1</td>
</tr>
<tr>
<td>Woodrow Wilson Fellowships</td>
<td>20</td>
</tr>
<tr>
<td>Hertz Foundation Fellowships</td>
<td>18</td>
</tr>
<tr>
<td>Other Industrial and Foundation Fellowships</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>398</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Assistantships</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching</td>
<td>462</td>
</tr>
<tr>
<td>Research</td>
<td>1,109</td>
</tr>
<tr>
<td>Graduate and Other</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,586</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sponsored Students</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Government Agencies</td>
<td>233</td>
</tr>
<tr>
<td>Industry and Foundations</td>
<td>129</td>
</tr>
<tr>
<td>Foreign Countries and International Programs</td>
<td>44</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>406</td>
</tr>
</tbody>
</table>

Total: Students receiving full tuition and stipend awards or otherwise believed to be fully supported 3,047

<table>
<thead>
<tr>
<th>Partial Awards, Loans and Miscellaneous Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual student support in many cases is derived from partial awards ranging from $100 to $3,000 each. In a few such cases, an accumulation of partial awards provides a student with essentially complete support. As a result, the number of such partial awards does not reflect the number of student recipients.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partial Awards and Adjustments from M.I.T. Funds</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Awards from Industrial and Foundation Sources</td>
<td>80</td>
</tr>
<tr>
<td>Recipients of M.I.T. Loans</td>
<td>463</td>
</tr>
<tr>
<td>National Science Foundation Summer Traineeships</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>642</td>
</tr>
</tbody>
</table>

516
Table V  Federal Support for M.I.T. Graduate Students

<table>
<thead>
<tr>
<th>Year</th>
<th>Atomic Energy Commission</th>
<th>Housing and Urban Development</th>
<th>National Aeronautics and Space Administration</th>
<th>National Defense Education Act</th>
<th>National Science Foundation Fellowships</th>
<th>National Science Foundation Cooperative</th>
<th>National Science Foundation Traineeships</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-1952</td>
<td></td>
<td></td>
<td></td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>1952-1953</td>
<td></td>
<td></td>
<td></td>
<td>46</td>
<td></td>
<td></td>
<td></td>
<td>46</td>
</tr>
<tr>
<td>1953-1954</td>
<td></td>
<td></td>
<td></td>
<td>51</td>
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<td></td>
<td></td>
<td>51</td>
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<tr>
<td>1954-1955</td>
<td></td>
<td></td>
<td></td>
<td>61</td>
<td></td>
<td></td>
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<td>61</td>
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<tr>
<td>1955-1956</td>
<td></td>
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<td></td>
<td>64</td>
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<td></td>
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<tr>
<td>1956-1957</td>
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<td></td>
<td></td>
<td>64</td>
<td></td>
<td></td>
<td></td>
<td>90</td>
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<tr>
<td>1957-1958</td>
<td>26</td>
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<td></td>
<td></td>
<td></td>
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<td>127</td>
</tr>
<tr>
<td>1958-1959</td>
<td>35</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>186</td>
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<tr>
<td>1959-1960</td>
<td>43</td>
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<td></td>
<td></td>
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<td>189</td>
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<tr>
<td>1960-1961</td>
<td>39</td>
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<td></td>
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<td>258</td>
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<tr>
<td>1961-1962</td>
<td>39</td>
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<td>313</td>
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<tr>
<td>1962-1963</td>
<td>34</td>
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<td>272</td>
</tr>
<tr>
<td>1963-1964</td>
<td>35</td>
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<td></td>
<td>15</td>
<td>4</td>
<td>100</td>
<td>39</td>
<td>186</td>
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<tr>
<td>1964-1965</td>
<td>41</td>
<td>15</td>
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<td>32</td>
<td>14</td>
<td>102</td>
<td>40</td>
<td>195</td>
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<tr>
<td>1965-1966</td>
<td>41</td>
<td>45</td>
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<td>15</td>
<td>25</td>
<td>152</td>
<td>42</td>
<td>258</td>
</tr>
<tr>
<td>1966-1967</td>
<td>45</td>
<td>45</td>
<td></td>
<td>29</td>
<td>25</td>
<td>165</td>
<td>44</td>
<td>272</td>
</tr>
<tr>
<td>1967-1968</td>
<td>45</td>
<td>3</td>
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<td>178</td>
<td>14</td>
<td>206</td>
<td>53</td>
<td>313</td>
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<tr>
<td>1968-1969*</td>
<td>36</td>
<td>7</td>
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<td>39</td>
<td>24</td>
<td>138</td>
<td>245</td>
<td>601</td>
</tr>
</tbody>
</table>

This table does not include data on the continuing National Institutes of Health fellowship and traineeship programs which had their inception in the 1940's.

*Estimated
The reports of the offices which are responsible administratively to the office of the Vice President, Academic Administration, follow in detail and bear testimony to a year of heightened activity and many constructive improvements in the support which these offices provide for our main educational mission. For purposes of highlighting the main developments or accomplishments in addition to serious problems that lie ahead, I have attempted to set down the following list. It includes:

1. As anticipated, we have had our share of interesting experiences arising out of increased student interest in political, social, and educational problems at the Institute. In my judgment we have been unusually successful, together with the students, in meeting these problems as they have arisen.

2. In previous reports I have consistently called attention to what I consider to be one of the most pressing problems at the undergraduate level; that is, the quality and quantity of male as well as female housing. This year we have made the most significant progress in this area since the end of World War II. During the year, McCormick East has been completed for undergraduate women, Eastgate has been completed for married students as well as young faculty, and construction was started for the new undergraduate house, MacGregor House. While this is a major step forward in one year, the demands upon us in the housing area in the future require or suggest that a capital fund of more than $10,000,000 could still be used effectively for these purposes.

3. This year has been the second one in which our policy for undergraduate student aid has made it financially possible for any young man or woman admitted to M.I.T. to attend without regard to financial need.
and without the requirement to work part-time. The experience of the past year again indicates that this policy is a very desirable one and has affected the quality of our entering classes significantly.

4. Again this year I should be less than candid if I did not admit that the high-priority need for undergraduate housing has influenced any unrestricted funds that might have been available for capital needs outside of the academic program. The result has been that financial needs relating to additional athletic facilities have not been met. I call attention to these major capital needs, outlined elsewhere by the Director of Athletics, Ross H. Smith.

5. The number of clinic visits to the Homberg Memorial Infirmary again increased by a significant amount. A steady increase in clinic visits over the last several years has made it necessary for substantial increases in space to be found for the purposes of the Medical Department. The availability of the Sancta Maria Hospital will help us for a temporary period with this space need, but for the longer run, studies of a new building for the Department are being initiated.

MALCOLM G. KISPERT

DEAN OF STUDENT AFFAIRS

This is the seventh report to the President which I have prepared since I assumed my present responsibilities in July, 1961. As I now marshall my thoughts following this hectic academic year, I find this report to be without doubt the most difficult I have attempted. It is difficult because the range of student concern, thought, and action, which seems to demand some permanent record, appears to have increased by almost an order of magnitude over those of the preceding six years — difficult because the complexities in each of the areas of concern to this office seem also to have increased many times over the past years — and difficult because there has not yet been sufficient time for assimilation and reflection to permit an accurate forecast of those issues which will be of long-standing importance and those which have been troublesome, immediate "crises" but whose importance will be of no lasting significance.

In order to achieve some semblance of order and brevity, I have chosen in my section of this report to focus on only two topics — the development of active student participation in political, social, and educational concerns at M.I.T., generally dubbed "student activism" by the popular press, and the progress in developing our undergraduate residential system. I report on the former topic because this of all
years has certainly been the students' year nationally and internationally and, although M.I.T. has been no exception, events at M.I.T. did not get out of hand and therefore did not receive broad news coverage as did those at many of our sister institutions. I report on the latter topic because I feel that M.I.T. — after skirting close to a crisis situation in providing housing for undergraduate men for several years — is now about to take those steps which will generate the necessary momentum to meet this challenge.

Prior to reporting in some detail on the more controversial student power efforts in the section on "student activism" which follows, I should cite briefly the steady increase of student-staff interplay in the more traditional areas of mutual concern at the Institute.

Although students have for years been voting members of several joint committees such as the Athletic Board and the Activities Development Board, most student-staff interplay outside the formal academic program has not been of a highly structured nature. Typically, the undergraduate student government has organized itself with a committee structure in large measure parallel to the structure of the faculty committees. Chairmen of the appropriate student judicial committees have sat regularly with the Faculty Committee on Discipline, but most of the other student groups met only sporadically with their faculty counterparts. The graduate student government (the Graduate Council) was even less involved and has only recently begun to develop a structure appropriate to the exploration of issues of concern to the graduate body.

During this past year, a definite trend has developed toward joint meetings of student committees and standing committees of the Faculty, such as the Faculty Committee on Student Environment and the Student Committee on Environment, and the Committee on Educational Policy and the Student Committee on Educational Policy. Further, as new committees were formed during the year, undergraduate and graduate students as well as faculty and staff were appointed as regular members of these new committees (for example, the Committee on Community Service). I personally view this trend as healthy for two principal reasons: the students often bring a perspective and a quality of imagination, which older members cannot be expected to possess, to the discussion of issues; and the students learn at first hand how decisions are made in the complex structure typical of most good academic institutions. To expand upon this latter point: I have been impressed with the difficulty some of the best of our students have in understanding the importance of persuasive argument and consensus
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taking in reaching decisions for action. Often these students mistakenly perceive the decision-making structure at M.I.T. as being a kind of line authority chain of command. I have also been impressed, however, with the ability of these same students — once they actually become involved in these processes — to achieve a quick understanding of and tolerance for the complexities involved so that they become extremely effective contributors to the joint committee efforts.

The trend toward dialogue and involvement became a campaign issue at the occasion of the undergraduate student elections in February. Miss Maria Kivisild ’69 ran on a general platform which promised more interaction among student leaders and “ordinary students” and among them and the staff. Her four masculine competitors ran on platforms which were more traditionally oriented toward the structure of student government and similar issues. Miss Kivisild won the election in a close preferential balloting and, since that time, has experimented with a number of different vehicles intended to achieve her communications goals (for example, open Inscomm meetings and discussions at unusual places and locations). Whether the “orderly M.I.T. minds” will feel comfortable with this rather unstructured form of operation is yet to be seen. At the very least, however, it is possible to predict that many more undergraduates than usual will be involved actively in one arm or another of the undergraduate government.

STUDENT ACTIVISM

In attempting to understand the change in the M.I.T. student mood over the past seven years, I have found it helpful to reread each of the introductory sections I prepared for the past six reports to the President. Albeit in an imperfect and perhaps superficial way, I feel the following excerpts do trace the development of a growing sense of awareness and concern of M.I.T. students for far more than formal classroom and laboratory education:

For 1961-62:

Despite the significant and rapid progress M.I.T. has made toward achievement of the character of a true university, many deficiencies remain. Students as well as faculty and administrative officers continue to express very real concern. Carl Wunsch ’62, editor of The Tech for 1961-62 . . . expressed this concern in an editorial published this past February.

“We do not know how close the Faculty thinks it is coming in arriving at its aims in undergraduate education here, but a great many undergraduates have had disturbing thoughts about their education . . . . Graduates are in many senses of the word professional people. . . . It is this professional competence that M.I.T. does so well in instilling in students; the other factors of life M.I.T. falls down in. . . .
"The tendencies of the four years here are to encourage a singleness of purpose that lies wholly within a narrow professional field, in many ways far removed from physical reality. . . .

"M.I.T. has set itself high goals for the second hundred years of its existence. If it hopes to have its graduates play as large a role in the coming century as it would like, it will probably have to change its atmosphere from one of purely scientific ferment to one of general intellectual upheaval."

For 1962-63:
The Admissions Office certainly does succeed in making impossible the literal discussion of the topic "the typical M.I.T. student." Undoubtedly, it is this diversity among our students and a similar diversity throughout the Faculty which provide the bases for the interesting and challenging life experienced by the Dean's office staff as we work with the students and the Faculty in a wide variety of situations. Our students sense the excitement and the challenge which pervade M.I.T. in the formal teaching and research programs. They bring to those areas of primary concern to the Dean's office a similar sense of "constructive dissatisfaction" with the status quo and a sense of responsibility and excitement as they work individually, in all-student groups, or in student-faculty groups. . . .

For 1963-64:
The severity of the nation's foreign problems, increasing racial tensions, and the mounting political controversies typical of a national election year certainly influenced many of the student body. But I believe it was the tragic assassination of President Kennedy which seemed to touch the heart and conscience of each and every student. Members of this student generation who had never before lived through national catastrophe — such as a major war or major economic collapse — seemed to become for the first time deeply and personally involved in all of the problems which beset our complex society. For many, this experience brought an awareness and understanding of the responsibilities educated men and women must assume beyond the immediate framework of their own personal and professional lives. They responded in many ways, but in almost all instances they responded thoughtfully and with a degree of sensitivity beyond their years. . . .

To provide channels through which students might help the less fortunate in the surrounding community, a small group formed almost spontaneously under the leadership of Amiel Shulsinger '64, Ann Kazanow '66, and William Sheftner '64. Joined by a number of graduates and undergraduates, they established the Social Action Committee to build upon and extend the long-established and effective community service work of the Social Service Division of the Technology Community Association (T.C.A.), Alpha Phi Omega, and the Interfraternity Conference. On their own initiative, these students brought to the campus, through discussion meetings and a specially prepared booklet, a new awareness of the problems of the underprivileged in the Greater Boston community. By the end of the academic year, the committee — now more aptly titled "The Social Service Committee" — had established a regular tutoring program at the Cambridge Neighborhood House in which 65 to 70 M.I.T. students participated regularly; had augmented the T.C.A. visiting program at the Boston Mental Hospital with approximately 20 additional student workers; had established a program in which about 25 students read for transcription on tapes for the Perkins Institute for the Blind; and had initiated a number of recreational programs for underprivileged children in the Cambridge area.

For 1964-65:
"It can't happen here!" This declaration formed the basis of remarks made to the M.I.T. Corporation by the President of the Undergraduate Association, William
C. Samuels '65. . . . He referred, of course, to those student uprisings at the University of California at Berkeley and other educational institutions. . . .

Mr. Samuels went on to support his thesis by developing his view of the qualities of mutual trust, respect, and openness which he felt characterized relations among M.I.T. students, faculty, and administration.

In all candor, I believe the M.I.T. Faculty and administration over many years have achieved a quality of relationship with a large fraction of the undergraduate body which encourages students to criticize, actively to debate, even to demonstrate — but to do so not in an alienated frustrated fashion, but with some degree of objectivity and with an awareness of their responsibilities both to the Institute and to the community at large. In short, we have had certain links which permit open and frank discussion of issues with large segments of the student population. . . .

The burden of my concern, then, is that we not be smugly complacent at the relative tranquillity of the M.I.T. campus over this past year, and further, that we fully recognize (and, in fact, applauded) the oncoming activist stage of student involvement in social and political issues. I suspect we will need to find new means to extend our ability to discuss, to argue, and to arrive at joint decisions with many more student groups than we presently see. In no sense do I wish to infer the establishment of an atmosphere of uniform "togetherness." Instead, I propose we need to find the means to expand to a broader spectrum of students the quality of relationship Mr. Samuels characterized. Our traditional reliance on our students' perception, responsibility, and common sense — with the establishment of an understanding as to where decision-making authority rests — has proved uniquely successful in the past. I would hope we can proceed in this vein without finding it necessary either to establish a complexity of rules and regulations on the one hand or the "big-brother" counseling concept on the other.

For 1965-66:

The following editorials written by John Montanus '66 for The Tech reflect the dynamic quality which is typical of M.I.T. On October 6 and 13 Montanus wrote: "This Saturday the M.I.T. Student Center will be dedicated. The ceremonies will last only 30 minutes. These brief minutes will culminate 13 years of student-administration cooperation. . . .

"Other buildings have been and will be dedicated this fall by the M.I.T. Corporation. But our dedication will be different. It emphasizes not science, but the lives and welfare of the people who create and use science. It is a family affair, not a national event; we are demonstrating to the Faculty, the administration, and ourselves that there is more to life and learning than books and classrooms. . . .

"The Center is not a panacea, nor the dedication the Last Trump. But on Saturday we celebrate a long-needed step in the right direction. . . .

"Now we must ask for a demonstration of that student spirit which makes the undreamed-of the inevitable. We call on Inscomm, for that body has the power, or even the duty, to make issues on this campus. . . .

"And we call on our critics — for in the past some have bemoaned the absence of issues and discussion. Take the initiative. Be specific and concrete. And we'll try to do our part to continue in the driving spirit of Saturday's ceremonies."

For 1966-67:

The facts are that we at M.I.T. are indeed lucky, if you will — lucky to have a long history of student-faculty-administration relations which are open and frank, a climate in which strong views from all segments of the community may be and have been expressed freely with respect for the rights of others to speak and act in opposition. In the past year, this campus has not been isolated from the turbulence of social and political upheaval in this country and abroad. Our
students have not been unconcerned about the relevance of their M.I.T. education to social and political issues, to themselves and to their own future roles in society; and certainly they have not submitted passively and without question to some of the glaring defects which still exist in the Institute's educational scheme of things. But their expressions of concern and their actions have been almost always carried out with a sense of responsibility, of civility, and most of all — with that inherent M.I.T. characteristic of participation in the solution in a constructively critical fashion. If I were to use the words "engineering mentality" to characterize the vast majority of M.I.T. students, I would do so in a complimentary, not a deprecating fashion. For, given the problems which face them, they typically do not choose only to find fault and place the blame; they also work hard at finding viable solutions...

Whether or not in the next several years we will be able to find the means to help our students come to grips with the problems which beset both them and us is an open question in my mind. I suspect that more than ever before, they will be groping for standards, for fundamental values, and the means to participate more actively in both Institute affairs and social and political issues outside the campus. Hopefully, we on the Faculty and administration will have the sensitivity and insight to meet these needs before we face a crisis in understanding.

The several guiding principles upon which we have relied traditionally in attempting to work cooperatively and constructively with our students during these past several years seemed to stand us in good stead during the year 1967-68 when — for the first time — the M.I.T. campus faced the possibility of major confrontations and/or major disruptions.

Provided that a proposed student organization was legal, we have not attempted to control student organizations that might achieve recognition of the student government and thereby the right to use the M.I.T. name, M.I.T. space, and internal communications media. If the organization was on the so-called Attorney General's black list, we asked only that the officers of the organization so inform prospective members in order that they might make their own decisions. Thus, over the past several years, student groups of almost all shades of opinion, from the extreme left to right, have been permitted access to campus facilities.

We have not attempted to control the speakers whom student groups asked to the campus, except to make certain that adequate precautions for safety were undertaken. Several years earlier, we had learned that the dilemma seemingly posed by the invitation of a highly controversial speaker to the campus — in that instance, Malcolm X — could in fact be converted to a significant educational experience. Similarly, a few years later, the dilemma posed by the impending performance by Dr. Timothy Leary, "high priest of the L.S.D. cult," became a nationally televised, constructive educational event. Dr. Leary more than met his match on the stage of Kresge Auditorium as he faced M.I.T.'s Professor Jerome Y. Lettvin. Thus, during 1967-68, the shades of con-
troversy represented by speakers brought to the campus seemed limited only by the availability of speakers willing to come to M.I.T.

We have had a long tradition of freedom of the press on campus. We have consistently refused to require that material to be published in student publications be cleared by a so-called advisor or other members of the faculty or administrative staff. (This is not to say, however, that the administration has not responded to clarify or to correct or to present the other side after publication of some controversial piece. Occasional heated "letters to the editor" attest to this fact.) During the past few years, this concept of freedom of expression which had been applied to the recognized student publications has proved to be a good ground rule to follow in dealing with the multiplicity of non-recognized publications — flyers and pamphlets — which have appeared regularly or sporadically to espouse causes of all kinds.

But if we as an institution did achieve any measure of success, not so much in handling student unrest, but in learning from it to be a better educational institution, this success resulted from our consistent efforts to foster every communications channel available — formal and informal. I emphasize that this was done by administrative officers, not with the hope of developing a tactical maneuver to outsmart the protesters at the time of confrontation, but to encourage rational debate on issues prior to their being escalated to the point of such fruitless confrontation.

Toward the close of the 1966-67 academic year, we had experienced a few anti-war protest meetings and a picketing of the R.O.T.C. Military Day Review on campus, but in the words of Michael Rodberg '68, editor of The Tech, "Utterly contrived, poorly managed, highly stilted, and non-spontaneous, the protest movement at M.I.T., had lunged forward, and fallen face down."

During the summer of 1967, the increasing frustrations resulting from this nation's involvement in the Vietnam war and the civil rights holocausts in Newark, Detroit, and elsewhere set the stage for considerably stepped-up student protest activity on almost all college campuses at the opening of the academic year. The initial targets chosen by activist student and faculty groups (among others) to draw attention to their cause were the Central Intelligence Agency (CIA), the Armed Forces, and the Dow Chemical Co., manufacturer of napalm. When the Placement Office announced the scheduling of placement interviews by Dow Chemical Co. for the period November 6 to 8, the ad hoc group which formed at M.I.T. to protest the interviews explained their selection of this target in a flyer distributed widely on campus in the following words:
DEAN OF STUDENT AFFAIRS

Why, then, has Dow been singled out for special treatment? To begin with, we do not have the organization or the manpower to picket every company that is making materials used in the Vietnamese war. We have singled out, as special targets, the armed forces, because of their intimate involvement with all phases of the war effort, and the CIA. Dow Chemical has been included because of the particular horror of its contribution. However, the demands we are presenting extend beyond Dow to the other companies whose products are used to carry out the war.

Since, among others, Harvard University had experienced a severe and disruptive confrontation by obstructive sit-ins and forced detainment of the interviewers sent by Dow to Harvard in October, we were particularly concerned that M.I.T. might experience a similar situation. The week preceding November 6 was a time of intensive conversation and formal and informal decision making involving essentially all elements of the M.I.T. community. For the students and staff who wished to utilize this vehicle of protest, the problem seemed to center upon the question as to how far to go in the direction of civil disobedience and obstructionism to achieve attention and recognition. For the Institute there were two basic problems. The first problem centered upon the proper balancing of what appeared at first sight to be two potentially irreconcilable opposing principles—the protection of the right of dissent with administrative policy in our democratic society on the one hand and the responsibility of the university to provide ready access to all informational resources for any of its students and staff on the other. The second problem focused upon what procedures might best be used should a massive confrontation, forcible obstruction, destruction or injury, and/or forced detainment take place.

In a statement released on November 1 and printed in The Tech for November 4, President Howard W. Johnson set forth the Institute’s position in these matters. Because I feel this statement will constitute both a basic policy and a point of departure for the operational implementation, at least for the near future, I include it in this report:

What do I think about protest by students on the presence of recruiters at M.I.T.?

Picketing of governmental and corporate recruiting activities on the university campus has become a major way by which student protesters choose to draw attention to their views on the present national policy in Vietnam. I understand that process and would be disappointed if our students did not have an opportunity to express vigorous dissent in a manner compatible with the obligations of membership in the Institute community. It is a principle of the university to permit, provide, and protect an environment where dissent is possible. I hope that visitors to our campus will understand this. On the other hand, it is important that such protest not become violent or abusive or interfere or limit the reasonable rights of others in the process. A second principle of the university is that members of our community should have access to information. I would be disappointed if an interest in such occupational information on the part of
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students were not present on our campus, and we have a responsibility to permit such access.

I am well aware that questions as to the appropriateness of some applications of these principles should be opened to discussion by students and faculty. But the way to consider such matters is by the kind of discussion appropriate to our open community and not by denying or damaging the rights of others. To infringe the rights of either protesters or those who seek information about jobs, inflicts grievous damage on the integrity and the long-run quality of the academic community.

Finally, let me say, the university should not be put into the position of meeting force on the part of people who abuse the privileges of the academic community. We have to rely therefore on the good sense and self-discipline of all of our members. I believe we can do so at M.I.T.

For their part, the students and staff who planned the protest (an amalgamation of members of the M.I.T. Students for a Democratic Society [S.D.S.] and the M.I.T. Committee to End the War in Vietnam) met several times and over the weekend decided (to quote a note which was sent to me Sunday evening, November 5), “It was the overwhelming decision of the meeting, which included undergraduates, graduates, teaching fellows, and faculty, to conduct (on the occasion of Dow Chemical Co.’s recruiting at M.I.T.) a non-obstructive sit-in to protest the war in Vietnam.”

On Saturday, November 4, several faculty members led by Dr. Murray Eden, Professor of Electrical Engineering and Master of Senior House, formed an ad hoc committee to explore means by which — again — the approaching dilemma might be turned into an educational opportunity. They conceived of a forum to take place at noon on November 6 as the first of what they hoped would be a series of such forums on “An Inquiry into Social Responsibilities.”

On the morning of November 6, the protest groups staged a rally on the steps of the Student Center, marched through the main buildings, and occupied the corridors outside the Placement Office in the Ford Building in a combination non-obstructive sit-in—teach-in session. There were a few tense moments — one in particular when the picketers found upon their arrival outside the Placement Office that the choice spots had earlier been pre-empted by anti-protest protesters from the Young Americans for Freedom (Y.A.F.). The latter’s theme was, “Are you seeing more of S.D.S. and enjoying it less?” Although demonstrators came and went, at any one time 100 to 125 lined the corridors until late afternoon, at which time they voted to disband and concentrate their efforts the next day — election day — at the Cambridge polling places.

At noon, Kresge Auditorium was filled to overflowing to hear the panel, hastily put together by the ad hoc faculty group, debate the issues of napalm and the Vietnam war. President Howard Johnson opened the
discussion, which was chaired by Professor Walter A. Rosenblith, Chairman of the Faculty. Professor Eden and Dr. Ithiel D. Pool, Professor and Head of the Department of Political Science, Dr. Philip Morrison, Professor of Physics, Dr. Frank Erwin of the Harvard Medical School and Dr. Max Key, Director of Industrial Relations for the Dow Chemical Co. participated in what was an informative but inconclusive discussion before an electrified but very respectful audience.

As the concern for war and peace grew, debate on and off the campus continued. On campus, the November 6 Committee, formed as the result of the Dow protest, seemed to become the leading doves while the Young Americans for Freedom represented generally the more hawkish view. This classification is, however, an oversimplification of very complex phenomena. Many doves on campus could not support the more radical methods of the November 6 Committee, and many Y.A.F. sympathizers supported the objectives of the doves but hoped to accomplish their objectives through more traditional political approaches.

Although the debates which followed "Dow Day" were comparatively mild-mannered, the announced arrival of recruiters for the Army at the Placement Office on February 28 and 29 seemed again to pose a problem similar to that which we had faced with the arrival of the Dow recruiters. By this time, the student protest leaders had gained considerable confidence so that the mimeographed flyers distributed around campus to announce the protest plans now used such words as "demand of the M.I.T. administration," whereas those for the Dow incident had typically used the words "request of the M.I.T. administration." It also became reasonably clear that the more militant of the student leaders were not about to have the design of any forum on the Army recruitment issue usurped by faculty. The student leaders of the November 6 Committee decided upon using the February 27-28 period as "Days of Opposition to the War." They held an evening anti-draft teach-in on February 27 in the Student Center in which about 70 people participated. On the morning of February 28 they assembled on the Student Center steps and led a march through most main traffic corridors of the Institute chanting "Peace now!" to the corridors outside the Placement Office where they participated in a sit-in – teach-in similar to but smaller than the earlier Dow event. They staged a noon-hour debate in Kresge Auditorium billed initially as "Professor Noam Chomsky versus the Administration" and finally as "Professor Chomsky and Professor Everett Mendelson of Harvard versus Nobody" – since, they said, the M.I.T. administration and others had been asked to defend their positions and roles in the war but had refused to participate. (To the best of my knowledge, I am the
only M.I.T. administrator who had been asked and had refused; I re-
fused because the invitation was issued the day before the event in a 
manner which led me to conclude I was expected to represent some form 
of institutional stand in complete support of the U.S. government 
policies.) The debate which took place before somewhat less than a 
capacity audience in Kresge thus became a kind of one-sided exposition 
of the anti-administration position. The rally which the leaders had 
scheduled to follow the debate on the Student Center steps was some-
thing of a let-down.

Although there followed attempts to have the undergraduate student 
government, the Institute Committee, take some official stand on the 
war issues, no formal endorsement one way or the other resulted from 
al of the debates on the issue. However, in early March the Graduate 
Student Council, following on its spring 1967 resolution opposing the 
war, voted 13 to 5 to recognize the establishment of the M.I.T. Anti-
Draft Union as a graduate student organization and stated the Council's 
"support of the moral commitment of those students who refuse to 
serve...."

Thus, throughout the late winter and early spring, student activist 
efforts seemed to move away from general demonstrations against the 
war toward means through which more specific action might be taken. 
Two broad thrusts began to emerge. One took the direction of support-
ing "Resist," a group encouraging young men to avoid the draft; spon-
soring the "Academic Days of Conscience" (scheduled for April 15 and 
16 as days for cancellation of regular classes in order to use the time for 
teach-ins, forum discussions and demonstrations); and sponsoring a 
general student strike scheduled for April 26. The second thrust took 
the form of active involvement in the political machinery then getting 
under way in preparation for the presidential primaries and election later 
this year. In particular, the ability of Senator Eugene McCarthy to 
speak to the issues of concern to students in a way which evoked both 
trust in him and a hope that he might be able to do something about the 
issues seemed to cause many students to foresake the New Left tactics 
in favor of the more traditional political procedures. They were joined 
by many of the middle-of-the-road, and the presidential preference poll 
sponsored by The Tech in May clearly demonstrated overwhelming sup-
port for McCarthy in this student body. The poll results reported on 
May 10 showed that — with 1,918 votes cast — McCarthy had 49 per 
cent of the first-choice votes, while his nearest rival in the M.I.T. vote, 
Governor Nelson Rockefeller, received only 15 per cent of the first-
choice votes.
The tragic assassination of Dr. Martin Luther King Jr. on April 4 seemed to result in a significant shift in major student concern from the war issue back to civil rights issues, which had been the major focus of student activism in earlier years. Although the civil rights activities which began several years ago had involved directly a comparatively small fraction of the campus, this year there seemed to be hardly a member of the M.I.T. community — particularly the student community — who in one way or another did not feel that his own life was deeply influenced by this tragedy and by the critical problems from which it had resulted. Over the weekend following the assassination there seemed to develop almost a step-function in understanding and concern and willingness to work to correct the ills, a change that might have taken a half-decade or more in development had not Dr. King been struck down. (And, to my mind, the most encouraging indication has been that I do not detect in our students any indication that there will be a gradual withering away of these positive forces as time heals the shock and revulsion of the King assassination. I believe this observation was correct during the time prior to the assassination of Senator Robert Kennedy, and, although I have not seen as many students since this second murder of a great political figure this year, those I have seen lead me to feel that the Kennedy assassination lent still added meaning to their commitment. I am certain that the vast majority will make good on the inner pledges I sense most of them have made.)

On Friday morning, April fifth, a small ad hoc group involving students, staff and alumni of all shades of political leaning gathered to plan an Institute memorial service for Dr. King in Kresge Auditorium that noon hour. President Howard Johnson opened the simple ceremonies, which consisted of selected readings from Dr. King's works by Robert Tinker, a graduate student in physics who had taught in the South and who had been active in the Social Service Committee; Mr. Gustave Solomon, a Negro alumnus of the Class of 1928; Stephen E. Straus '68, Chairman of the Social Service Committee for 1967-68; Maria L. Kivisild '69, Undergraduate Association President for 1968-69; and Professor Willard R. Johnson of the Department of Political Science, one of the few Negro members of the Institute's teaching staff. Harold R. Isaacs, Professor of Political Science who was a lifelong friend of Dr. King, said in closing the service that Dr. King's death was in one sense more lamentable than that of President John F. Kennedy: it was brought about by a "much more namable madness . . . that we have all experienced . . . that we all share in some way or other. The question now is what we do about it, each one of us beginning with himself."
During the weekend, an Institute Committee meeting which originally had been scheduled to discuss business matters was converted to a planning session to develop a means through which the M.I.T. community might take stock of the issues and discuss plans for the future. Fortunately, several members of the Faculty and administration had been invited to attend the originally scheduled Inscomm Open Meeting so that, again, it was possible for students, faculty, and staff to plan constructively together. The result of this cooperative effort was reported in the June, 1968, issue of *Technology Review* as follows:

Two panel discussions brought more than 1,000 members of the M.I.T. community to Kresge Auditorium on Tuesday morning, when classes were canceled from 9:00 to 1:00. Among the speakers on Racism in America and later on “Where Do We Stand?” (meaning M.I.T.'s position and potential): Philip Morrison, Professor of Physics, traced the history of the “profound meaning of polymorphism in man,” predicted the eventual remixing of the races as a product of the machine age, and called for an approach to race problems “in cool reason and warm dedication, so that we can proceed with hope.”

Leonard J. Fein, Associate Professor of Political Science, commented on the change from “prejudice” to “racism” in the last ten years — an admission, he said, that “the problem is embedded in our institutions. We support an institutional environment which brutalizes the Negro,” he declared.

Jerome Y. Lettvin '47, Professor of Communications Physiology, said that Dr. King was “the man who voiced the universal ‘no’ against injustice, wherever it happened.”

Roland B. Greeley, Director of Admissions, announced M.I.T.'s plan to admit a number of Negro students next fall who could not meet the usual entrance requirements, and he and Leon Trilling, Professor of Aeronautics and Astronautics, discussed other proposals such as a plan for a summer program for 20 to 30 Negro high school graduates as preparation for college careers, or a similar year-long plan for 100 students. To these plans came an answer from Shirley A. Jackson '68, that whatever M.I.T. could do would be too little and too late; indeed, she asked can society possibly change rapidly enough? In turn came a vigorous response from a Negro student in the audience, who charged that the whites present were hypocrites and that the white man doesn't really feel what he says about the black man.

Meanwhile, outside stood the most tangible expression of the Institute's grief and resolve — a memorial exhibit covering almost the entire plaza between Kresge Auditorium and the Student Center with black banners, boards displaying pictures and words of tribute, boards with paper for viewers to write their affirmations, tables and chairs for discussion, and booths for student committees. It was the work of Maria L. Kivisild '69, Stephen A. Leff '68, Arthur M. Stern '68, and John H. Terry '68, all architecture students, and of dozens of students and faculty who worked in shifts throughout Monday night to have the whole ready for the Tuesday memorial events.

Although classes were officially suspended from 9:00 a.m. to 1:00 p.m. on Tuesday, April 9, the November 6 Committee began early on Monday morning, April 8, to call for all students and faculty to boycott classes Monday, Tuesday, and Wednesday “to use these three days to begin their active participation in advancing the cause for which Dr.
King gave his life: to end racism and the war in Vietnam." To my knowledge, no classes were canceled and, although class attendance is not normally taken at M.I.T., impressions of most instructors were that attendance was about normal. It is probably too early to make a full assessment of this move on the part of the November 6 Committee, some of whom had participated actively in the student-faculty-staff planning session mentioned earlier, but I suspect considerable good faith was lost through the methods and tactics exhibited by this boycotting group.

Some time earlier the Social Service Committee had planned a week-long effort to bring the social needs of the greater Boston community in better contact with the services and capabilities of the M.I.T. community. Again from the Technology Review:

A very different expression of community commitment came a week later (April 15-20) when more than 1,000 M.I.T. students took time from their academic and collegiate pursuits to work on community projects for more than 130 service agencies throughout the greater Boston area. "Operation Target" was organized by Thomas C. Woodruff '70, Chairman, and other members of the M.I.T. Social Service Committee. Alfred S. Callahan '71, who directed "Operation Target," said there was work for at least 1,800 students during the week. The city of Cambridge alone, he said, asked for 600 volunteers to work on playgrounds, settlement houses, and public works projects. One group traveled to Camp Massasoit in Plymouth, where they cleared the grounds and prepared the camp for summer activities for underprivileged children. Twenty students helped the American Cancer Society collate cancer kits each day; 15 students worked at the South End Neighborhood Action Center to set up a library and kitchen, and several Greater Boston Area Planning Action Councils used students to organize information programs and conduct surveys.

A call to suspend classes for the "Academic Day of Conscience," April 15, went essentially unheeded, but a significant number of students attended several teach-ins and other forums on racism, black power, and so on. The newly formed M.I.T. Black Student Union combined with the M.I.T. November 6 Committee and the M.I.T. Students for a Democratic Society in sponsoring one such event in the Student Center on May 2 in which representatives of the United Front in Roxbury, CORE (Congress on Racial Equality), and the Roxbury Freedom Security Patrol participated. Similar events in a number of the student residences were very well attended by M.I.T. students who wanted to get whatever facts they could in order that they might decide how best to take appropriate action.

As the term drew to a close, each day seemed to bring still another idea from either an organized or ad hoc group of the M.I.T. community as to how M.I.T. might make significant contributions across the broad front of social and political issues. The thoughts and actions of staff and
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students alike seemed to reflect in many ways the words of one sophomore who said, "I gained a sense of personal commitment; I finally recognized that the real issue was my wish to be recognized as an important part of society in order that I might do 'my thing' to help."

Just how M.I.T. can best marshal what inevitably must be limited resources in order to maximize the impact of our research, educational, and extracurricular efforts on these massive and complex problems remains to be determined. Unlike many educational institutions, M.I.T. has, since the days of William Barton Rogers, been intimately concerned with the real-world problems of the present and future. M.I.T. has exhibited time after time a unique ability to marshal the talents of all members of the community to face these problems. In my view there is every reason to believe that the present somewhat chaotic, diverse (and sometimes divisive) efforts on the part of many individuals and groups at the Institute will come together over the next few years in order to attack cooperatively those tasks for which this community is best equipped. Indeed, if M.I.T. — with an entire history of commitment to a change for the better in society, with a great tradition of student and staff cooperation and commitment, and with an unusual ability to move — if M.I.T. cannot make significant progress, what educational institution can?

STUDENT HOUSING

As I observed in the preface to this report, our problems in providing adequate student housing have been mounting in severity over the past several years. Fortunately, we were able to complete and occupy two major additions to our on-campus residential structures this year.

As Dean Wick reports in a subsequent section, McCormick Hall East, a new addition to the undergraduate women's residence, was presented to the Institute by a gracious benefactress, Mrs. Stanley (Katherine Dexter) McCormick '04.

Eastgate, the Institute's new apartment residence for married students and young faculty families located on the Sloan Campus, was ready for occupancy by the opening of the fall term, 1967. One hundred ninety-eight families reside in this tower structure designed by Professor Eduardo Catalano of the Department of Architecture. In addition to the residential space in this building, there are facilities for the Technology Nursery School (in addition to those at Westgate) and considerable commons areas. Although some gift capital was used to finance the non-residential areas in this structure, the major portion of capital cost is being amortized from the rental income under low-interest, long-term U.S. government financing.
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With the addition of Eastgate to our Institute-owned resources for married student housing, we were able in September, 1967, to house 384 married student families out of a total of 1,644 (1,504 graduates and 140 undergraduates) or slightly less than 25 per cent. Similarly, in Ashdown House, the Institute's old residence for single graduate students, we provided housing on-campus for 435 (405 men and 30 women) out of a total of 1,840 single graduate students — again slightly less than 25 per cent.

Thus, more than 75 per cent of our graduate population and more than 500 undergraduates not residing in an Institute House or fraternity, or at their family homes found accommodations in apartments and rooming houses in the Greater Boston area. Many of these students had great difficulty in finding places to live, and many ended up living in very low-quality and/or very high-rental facilities. The Campus Housing Office of the Community Housing Service has performed near miracles in attempting to find suitable residential space for this large number of students (not to mention similar problems associated with locating adequate housing for new faculty and staff). But the sheer fact of the matter is that the demand for such housing in this area has long since outrun the supply, and the market is indeed a seller's market.

This year, in recognition of these critical problems, the president appointed a special task force under Philip A. Stoddard, Vice President, Operations and Personnel, to make a complete assessment of our anticipated housing needs through 1980 and to study and recommend means by which the Institute might add both to its own housing resources and those of the surrounding community. At this writing, the task force has completed the initial study and is about to make specific recommendations for action in the construction of Institute-owned on-campus facilities and off-campus facilities, financed through the private sector.

Since the need for housing for undergraduate men is probably the most critical of all of those housing demands and since our program planning for this segment of our population has been under the most intensive study for the past six years and is therefore more fully developed, I feel it is appropriate to expand upon these programs in the following sections.

UNDERGRADUATE MEN'S HOUSING

As we have attempted to meet the increased demands both for quantity and improved quality of housing, we have continued to support the concept of developing a housing program for single undergraduate men which is diverse in character and location. Through this approach we hope that each student will identify with a living group that matches his
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needs and aspirations closely — but one which is nevertheless of high quality; which is supportive of the intellectual, social, and cultural development of students; and one which imparts a sense of taste and style.

Thus the housing program which has evolved for undergraduate men is one that is really a conglomerate of several subprograms, each of which requires massive attention and assistance at the present time. Within the Institute-owned student residences, we must build new structures, remodel some old ones, and abandon to other uses still other “permanent housing” structures and two so-called “temporary auxiliary dormitories.” Our fraternities face problems similar in many respects to those facing M.I.T. as we look to improve Institute-owned housing. The fraternities are also faced with the necessity of building new structures, remodeling older structures, and, in some cases, abandoning present structures and locations completely. Finally, since we propose to continue to make it possible for upperclassmen who for their own reasons choose not to live in an Institute House or a fraternity but within the surrounding community, we must find better ways to assist these students — as well as graduate and married students who do not live on-campus — in locating decent housing. Of even greater importance within this crowded Boston-Cambridge area, we must find ways to reduce the pressure for housing placed by students on the indigenous population by adding to the “housing stock” of the Cambridge-Boston community.

THE INSTITUTE HOUSES

For the academic year 1967-68, the four “permanent” and two “temporary” Institute Houses were filled to their capacity of 1,717. Thus approximately one-half of the undergraduate male population of 3,600 resided in the dormitory system.

Of the four permanent houses (Baker, Burton-Conner, East Campus and Senior House), only Baker House (the dormitory completed in 1949 with a capacity of 354 undergraduates) approaches a level of quality which we feel should characterize our M.I.T. residential unit.

Senior House (the first new dormitory constructed on the Cambridge campus in 1916, capacity 191 undergraduates) seems to provide the best student room arrangements in the form of suites and entries, but this house lacks sufficient commons facilities. Further, no major renovations of Senior House have been undertaken since its construction in 1916 and this structure is thus in need of major remodeling and upgrading if it is to continue as a satisfactory student residence.

The East Campus parallels (constructed from 1924 to 1931, capacity 406 undergraduates) represent the utilitarian approach to student hous-
ing that characterized the M.I.T. era during which they were constructed. The single student rooms are good bed-study rooms, but the 300-foot-long "bare and beaten" corridors and the absence of lounge-meeting-commons rooms in these buildings have consistently mitigated against the development of good quality of student living-learning environment in these houses. Fortunately, with the help of the alumni fund and other grants, we were able to upgrade two of the ten floors of these buildings last year; we shall complete the upgrading of the remaining eight corridors this summer and at the same time provide two small lounges on each floor to foster group interaction. These latter will be particularly important for the coming few academic years because it will be necessary to double up a considerable number of single rooms in East Campus to meet the projected demands for over-capacity dormitory bed space which we shall face until new house construction is completed and available for assignment. Thus, we regard these renovations as extremely important but nevertheless stop-gap measures, pending our ability to undertake a truly first-class effort.

Burton-Conner, the fourth and last of the permanent houses, is the old Riverside Apartment-Hotel on Memorial Drive. The Institute purchased and renovated this building in 1949-50 to meet the postwar housing crisis which precipitated the housing of undergraduates barracks-style in the temporary World War II Radiation Laboratory structures. At that time, the effort was to revamp the old apartment building as quickly and cheaply as possible to house as many men as possible. We are now faced squarely by the long-term implications of this short-range solution. Although — through alumni fund and other help — we have been able to provide a good dining facility and some good commons facilities in this house, the student room areas are terribly run-down, overcrowded, noisy, and generally depressing. Because we desperately need the 542 undergraduate beds in this structure to accommodate the ever increasing demand for dormitory space, we shall not be able to make any truly significant impact on the physical support to good student life in Burton-Conner until we can empty parts or all of the building into new structures and then undertake the truly major remodeling now long overdue.

The two temporary houses are Bexley Hall and Random Hall. Bexley Hall is the old apartment building directly across Massachusetts Avenue from the main buildings, which we converted to undergraduate men's housing in 1963 to meet the increasing demand for dormitory accommodations. Presently, some 126 undergraduates are housed in this run-down building. We have been able to provide a small games room and
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commons room in the basement. We plan to begin a program of modernization of the antiquated plumbing this summer, but this will be done only with a view to keeping the building in operation for some five to ten years, at which time we hope to be able to abandon it as an undergraduate residence.

Random Hall is the old "railroad-style" rooming house north of the Institute at 282-290 Massachusetts Avenue. We rented and renovated this old structure to house 100 undergraduates for the first time during 1967-68. The title Random Hall is the imaginative name given to this structure by the undergraduate occupants when they took up residence; the selection of this name was certainly influenced by our difficulties in making the structure ready for occupancy. Although we had planned that the necessary renovations would be completed by the opening of the fall term 1967, several unavoidable delays resulting from the contractor's labor disputes forced us to find interim housing for the approximately 100 undergraduates assigned there. Accordingly, some of this group were housed at 27 West Street, Cambridge, the small apartment building which had been used as a temporary undergraduate house for 1966-67, and the remaining men took over several apartments in Eastgate, the Institute's new married student apartment structure on the Sloan Campus. There were numerous trials and tribulations resulting from the split location of the house population and from the mix of boisterous young unmarried men and the families of married graduate students and faculty in Eastgate. In the long run, good humor triumphed, however, and the undergraduates moved to Random Hall at the mid-term break. Their gala dedication or housewarming on February 29 gave every indication of a strong and unified house spirit.

Although the new paint and furnishings make Random Hall a reasonably pleasant structure right now, the cosmetic nature of the renovations is such that we must plan to abandon this structure as part of the Institute's House system within about the same time period as Bexley Hall.

But despite the generally negative tone of the foregoing comments, two recent steps the Institute has been able to make in the direction of major new construction and improvement are most encouraging. The first is the beginning of the construction of MacGregor House, the Institute's first new men's dormitory in two decades, which will rise on the Memorial Drive site just west of the No. 6 Club (Delta Psi). Scheduled for occupancy in February, 1970, this first of the new generation of M.I.T. undergraduate men's residences will house 324 men — small individual rooms will be arranged in suites, the suites will be arranged in entries,
and the entries, together with commons and dining rooms, will form the house. We are greatly indebted for the generosity of Frank S. MacGregor '07 who has made it possible to begin this long-planned program.

As the second step — upon the completion of MacGregor House — we will close down and remodel Burton-Conner in two phases. Thus, by February, 1972, or June, 1972, at the latest, Burton-Conner will be completely remodeled to a program closely paralleling that of MacGregor House. During this process, the capacity of Burton-Conner will be reduced from the present overcrowded 542 to a very comfortable 350 to 400, depending upon the specific remodeling plan chosen.

We will then require the construction of at least one additional new undergraduate men's house on the West Campus. At present, we are well along in the preliminary design studies of this house, to be located just west of MacGregor House and to share the kitchen of MacGregor.

With this second new house available for student occupancy, we must face up to the long-term use of East Campus and Senior House. If we decide to continue these as undergraduate men's houses, we will necessarily have to undertake extensive renovations in each. If we decide to use these buildings for other purposes, we must build two additional new West Campus houses, each of about the same capacity as MacGregor. In either case, it will be possible upon completion of remodeling East Campus and Senior House or, if these are abandoned and two new houses built, to abandon the use of the present two temporary houses, Bexley and Random Halls, for housing undergraduate men.

Upon completion of this program, we shall have a capacity of approximately 2,000 in the Institute-owned undergraduate men's housing system. All of these accommodations will be of good quality and all will be in residential units which — while diverse in style and location — will possess the physical facilities to complement and supplement the formal academic program and to foster cultural and social development.

The major problem is, of course, financial. Costs of new construction and remodeling are such that we cannot amortize any significant portion of these costs from student rental income under presently available commercial funding. Thus we must look to major infusions of gift capital and the availability of low-cost, long-term government loan programs as the means to accomplish the task. It is an unfortunate fact, but nevertheless one we must face, that most of the capital costs of student residential buildings of the required character and quality to accomplish our residential-educational goals (and to be competitive with other universities) must be treated in the same manner as the capital costs of academic structures.
THE INDEPENDENT RESIDENCES

For the year 1967-68, our so-called Independent Residences — 27 chapters of national social fraternities, one local fraternity and the co-operative Student House — also operated beyond capacity. During the fall term some 1,322 undergraduate men in the fraternities and M.I.T. Student House were distributed as follows:

- 4 fraternities in Cambridge: 150
- 2 fraternities in Brookline: 102
- 22 fraternities and the Student House in the Back Bay (27 buildings): 1,070

Of this total, 167 men who were affiliated with fraternities but who could not be accommodated in the chapter houses because of space limitations resided in nearby apartments.

The four houses located adjacent to the Cambridge campus on Memorial Drive enjoy the most comfortable location of all. In addition to the obvious advantages associated with a location contiguous to the campus and with the amenities of a river-front location on Memorial Drive, these houses are also free for the most part of hostile neighborhood friction problems and restrictive zoning ordinances imposed by the City (although they must conform to certain safety and building standards).

Of these four, Theta Delta Chi is well fixed in a recently remodeled and expanded structure that was until a few years ago Moore House, home of the Dean of Residence. Phi Beta Epsilon is well along on financing and construction plans to gut and remodel the present structure to bring it to a high standard of quality and to house a larger number of students. Delta Psi (“The No. 6 Club”) — although plans have not progressed as far as Phi Beta Epsilon — is also actively exploring plans to augment both the capacity and quality of the present chapter house. Finally, Delta Kappa Epsilon has recently begun a similar study aimed at longer-term upgrading of the Deke House.

Of the two fraternities located in Brookline, Zeta Beta Tau is comfortably fixed in a relatively new building that originally had been designed and built as a fraternity house for the Sigma Alpha Epsilon chapter of Boston University and which was purchased by the M.I.T. Z.B.T. group when the latter went bankrupt. Z.B.T. has carried out a number of renovations during the past two years so that this chapter is physically well fixed. Our Sigma Nu chapter in Brookline has, however, been faced recently by a series of requirements placed upon them by the Town of Brookline, some of which have been difficult to meet. This
large old frame “family” structure was remodeled extensively at consider-able cost to Sigma Nu a few years ago. At that time the chapter felt the house had been brought up to standard. But subsequent changes in licensing laws which require a minimum of 90 square feet per man in their dormitory-style sleeping area, if rigidly enforced, threatened the house with a significant reduction in capacity. Recently, in acknowledge-ment of the chapter’s installation of added sprinkler systems in the stairways, the town has granted Sigma Nu a waiver of the sleeping room area requirement for an indefinite period.

The situation faced by the remaining 22 fraternities and the Student House located in Boston’s Back Bay is considerably more complex. Rapid increase in the number of educational institutions in this area (many of which enjoy real estate tax-free status), the resulting large in-crease in transient student population residing in both institutionally owned student residences and rooming and apartment houses, the influx of hangers-on or “kids looking for trouble on weekends,” and the flight of the older, more stable residents — all have contributed to the de-terioration of the quality of life in the Back Bay. The permanent resi-dents and certain real estate interests have reacted understandably nega-tively toward students in general. The City of Boston has also passed restrictive zoning laws aimed both at limiting the size of the student population and conserving the tax rolls of the city. Twelve fraternity chapters (with 14 buildings) are presently located in the so-called H5 zone of the Back Bay, where fraternities are a “forbidden” use, and ten fraternities and the Student House (with 13 buildings) are presently located in the so-called H4 zone of the Back Bay, where fraternities are a “conditional” use. Those located in the H5 zone may exist under a “grandfather clause,” but they cannot convert additional properties in this zone for their use and they are severely limited in the amount of re-modeling and expansion work which they are permitted to carry out on their present properties. Although these restrictions are not so severe for the houses located in the H4 zone, considerable red tape — includ-ing approval of abutters — is required to carry out extensive changes in their physical plants.

Of the Back Bay houses, a number have carried out major upgrading; some are presently undertaking considerable work, subject to zoning restrictions, and still others are actively exploring several alternate courses of action.

Those that have remodeled include Delta Upsilon, which undertook a major effort some six years ago; Phi Kappa Theta and Pi Lambda Phi, each of whom lived outside their chapter houses during portions
of the last academic year so that extensive remodeling could be undertaken; and Theta Xi, which two years ago acquired a structure next door to the older chapter house and remodeled both houses to effect a marked increase in capacity and a reduction in overcrowding. Considerable remodeling work is presently under way at the Tau Epsilon Phi house.

Five fraternities — Alpha Tau Omega, Kappa Sigma, Phi Sigma Kappa, Sigma Alpha Epsilon and Sigma Nu (all except Sigma Nu presently located in the Back Bay) — joined forces during this academic year to form the Fraternities Collaborative. This informal association resulted from a series of discussion meetings among alumni and undergraduate officers of individual fraternities with officers of the Alumni Interfraternity Conference (A.I.F.C.), officers of the Interfraternity Conference, and members of my staff. At this writing Fraternities Collaborative is actively exploring the development of a program through which these houses might undertake new construction in such a way as to maintain considerable chapter individuality but at the same time take advantage of those economies of scale which are hopefully associated with larger construction projects.

Three neighboring houses — Phi Kappa Sigma, Sigma Chi, and Theta Chi — are presently considering the formation of another collaborative with a view toward undertaking either new construction or major remodeling of their present structures in a cooperative venture. Still others — Alpha Epsilon Pi, Beta Theta Pi, Lambda Chi Alpha, Phi Delta Theta, and the M.I.T. Student House — are considering the advisability of forming a cooperative study group, if for no other reason than continuously to monitor and assess developments in the particular area of the Back Bay in which they are presently located — upper Bay State Road.

Finally, Chi Phi, Delta Tau Delta, Phi Gamma Delta, Phi Mu Delta, Sigma Alpha Mu, and Sigma Phi Epsilon are individually taking stock of their present situation to assess what long-range plans are most appropriate to their individual situations.

Not specifically stated but certainly underlying the present state of looking ahead which is apparent in the above survey of our "independent residences" is the Institute's long-term commitment to this form of student residence. Not only do these houses provide physical facilities which the Institute would be hard pressed to provide should our independent residences cease to exist, but more fundamentally, they provide an important element of the diversity we seek to provide in our undergraduate residential pattern. Also, they are continuing to develop,
as are the Institute Houses, as strong contributing partners toward the Institute’s goals of first-quality living-learning residential programs.

It is also clear that cooperatively with the A.I.F.C. we must identify massive capital resources to finance either the major remodeling or new construction required if these houses are to continue as viable segments of the undergraduate residential program. The Independent Residence Development Fund of the Alumni Fund, which provides a revolving fund for long-term, low-interest mortgages to these houses, appears to be the most promising vehicle through which these financial needs can be met. Since direct gifts to fraternities are not deductible under present income tax laws, it is unlikely that many fraternities will be able to finance major portions of their capital requirement through direct gifts. Since the establishment of the I.R.D.F. in 1965, $550,000 has been generously given by alumni. Of this, more than one-half has already been loaned to fraternities. Much much more will be required to accomplish the task we see ahead.

STAFF

I can recall clearly a very beloved older professor counseling me in my own undergraduate days at M.I.T. with these homely words: “To be a true success, you’ve got to like your work, enjoy and respect the people with whom you are working, and, once in a while, you have to have a ‘pat on the back’ for a job well done.” I have seen no reason to question the validity of this advice over the intervening quarter-century and, so, in this formal report, I take the opportunity to “pat on the back” each member of my staff, as well as many others closely associated with me at the Institute, for their outstanding performance during this last year. Each staff member must certainly have liked his work and his associates or he or she would not still be with us after this exceptionally harried and trying year. The entire staff deserves sincere thanks for quietly, efficiently, and without complaint undertaking far more work in a much more complex and fast-moving era than I had predicted when I made my staffing plans toward the close of last year.

Professor Paul E. Gray ’54, who has served as Chairman of the Freshman Advisory Council since 1964 and as Associate Dean of Student Affairs with primary responsibilities for freshmen as Executive Officer of the Freshman Advisory Council (F.A.C.) since 1965, became Assistant Provost in December. In his new role, Professor Gray will continue to maintain contact with the Dean’s staff as he works with the Committee on Educational Policy and other committees and individuals on the Faculty and staff toward continued improvement of the curriculum, teaching, and structure of the freshman year.
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To succeed Professor Gray, Professor Gian-Carlo Rota of the Department of Mathematics has accepted the president's appointment as Chairman of the Freshman Advisory Council and Peter Büttner '61, has moved from the position of Assistant to the Director of Student Aid to that of Assistant to the Dean of Student Affairs and Executive Officer of the F.A.C. Kenneth E. Schoman '67 who, as Assistant to the Dean of Student Affairs, has devoted approximately half-time to freshman-year concerns this past year, will move to a full-time appointment effective July, 1968, to assist both Professor Gray in his new role and Professor Rota and Mr. Büttner in the Freshman Advisory Council program.

Kenneth C. Browning '66 has served as Assistant to the Dean of Student Affairs on a part-time basis with responsibilities both in the freshman and student housing areas since 1966. He will leave our staff at the close of this academic year to assume a new full-time role as assistant to Laurence H. Bishoff on the staff of the Campus Housing Office. With Mr. Browning's transfer, we will complete the planned transfer of responsibilities for most of the operational aspects of Institute housing from the Dean's office to the Campus Housing Office.

Professor David C. White has resigned, effective at the close of this academic year, as Master of Burton-Conner, in order that he and Mrs. White can spend two years at the Birla Institute in India on a special educational development program under the Ford Foundation. Professor White has been a most dedicated and imaginative contributor to the developing house master-tutor system since his appointment in 1963.

Professor Herbert H. Woodson '52, Philip Sporn Professor of Electrical Engineering, has accepted the President's appointment as Professor White's successor. No stranger to on-campus living, Professor and Mrs. Woodson were residents of the old Westgate village during his student days immediately following World War II. They and their three sons look forward to renewing their contributions to life on campus in this new role.

Professor E. Lee Gamble, Master of Baker House, will take a one-year leave of absence for 1968-69, in order that he and Mrs. Gamble may also work on new educational programs at the Birla Institute. We are indeed fortunate to have Professor Isadore Amdur '30, a well known teacher-researcher in the Department of Chemistry, and Mrs. Amdur "pinch-hitting" for the Gambles for this coming academic year.

Effective July 1, 1968, Professor Prescott A. Smith '35 of the Department of Mechanical Engineering has been promoted from the position of Faculty Resident to House Master of Bexley Hall, and Professor Alvin W. Drake '58 of the Department of Electrical Engineering has been
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promoted from the position of Faculty Resident to House Master of East Campus.

Professor C. Duncan MacRae of the Department of Economics has resigned as senior tutor of Baker House effective at the close of this year, a post he has held since 1966. John G. Kassakian '65, instructor in Electrical Engineering, will succeed Professor MacRae.

Professor Frank C. Colcord of the Department of Political Science has also resigned as senior tutor of Senior House effective at the close of this year. Professor Colcord, who has held this post since 1965, will be succeeded by Professor Robert J. Silbey of the Department of Chemistry.

Last, Ronald A. Walter '64, instructor in Civil Engineering, accepted appointment at the beginning of this past academic year as Faculty Resident of Random Hall. To Mr. Walter and his wife we owe considerable credit for their help in easing the pains of transition of this new Institute residence from a disparate group in two locations to a full-fledged house operation in Random Hall.

As in the past, I have asked several of my associates to report on those areas for which they carry primary responsibilities. Their reports follow.

KENNETH R. WADLEIGH

THE FRESHMAN YEAR

THE FRESHMAN ADVISORY COUNCIL

The F.A.C. is comprised of approximately 110 members of the Faculty who are drawn from those departments having undergraduate teaching responsibilities. These members of the F.A.C. are responsible for the counseling of all freshmen and of about one-quarter of the second-year students, that quarter that has elected to postpone a selection of course or department until sometime during the second year. Each member of the F.A.C. has responsibility for approximately ten students. These relationships are not only the source of academic and career counseling; in many cases they constitute the first line of personal counseling as well.

Through its Executive Committee, the F.A.C. also oversees two programs which are important components of the undergraduate educational experience. These are Freshman Weekend and Course Orientation. Since both of these programs have been under active study by the F.A.C. Executive Committee during the past three years, and since each has changed and is changing to reflect the important modifications that have occurred in the undergraduate program since 1964, I take this opportunity to review both the objectives and nature of these programs.
FRESHMAN WEEKEND Each year the freshmen arrive at the Institute five days prior to Registration Day and the start of classes. During this period, traditionally called Freshman Weekend, the entering students meet several times with their advisors, attend a variety of orientation meetings, and participate in a rich variety of activities planned and executed by upperclass students, intended to introduce the new students to the campus, to student activities, to student government, and to the living groups. In terms of the responsibilities of the F.A.C., Freshman Weekend serves two principal objectives. First, it provides an opportunity for individual advisors to become acquainted with the students for whom they are responsible. Second, it introduces the freshmen to the academic environment of the Institute and helps them make decisions concerning the nature of their personal academic programs, decisions which are of major importance in terms of the adjustments which these students make to a new, demanding, and highly competitive environment. Since the academic programs of individual first-year students can differ in major ways in both the selection and timing of subjects taken, these decisions are by no means trivial.

The dilemma that faces both a freshman and his advisor during Freshman Weekend grows out of the requirement that a substantive decision concerning academic program be made at a time when the freshman has no personal experience with the Institute. Specifically, a freshman must, after consultation with his advisor, decide upon the set of subjects which will comprise his program at a time when he has minimal personal knowledge of M.I.T., of its academic expectations, of its pace and intensity, and of his preparation for specific subjects. The advisor who participates in these decisions is faced with similar problems; his personal knowledge of the capabilities and objectives of his students is similarly less than it will be at any time later in the year.

We have dealt with this critical problem of Freshman Weekend — this gap of information and personal experience — in three ways. First, we have attempted to provide the entering students with more useful information of an academic nature earlier. Thus, a booklet which focuses on academic matters, and which is mailed to freshmen early in the summer, has evolved over the past three years. Called Academic Information for Freshmen, this publication describes the principal curricular alternatives in the first year and raises the issues which are important in arriving at curricular decisions. In addition, we have introduced into the Freshman Weekend program several activities intended to clarify academic issues. Thus, academic alternatives and expectations are discussed at a meeting of the entire class. Professors in charge of the freshman
core subjects and the Undergraduate Planning Professor have participated in these discussions. Also, we have introduced opportunities for freshmen to meet, individually or in small groups, with professors in charge of the principal elective subjects open to freshmen.

Second, we have tried to identify, and to make available to both freshmen and their advisors, meaningful predictors of academic readiness which they may use both in selecting a set of first-year subjects and in deciding upon their timing. These efforts have ranged from an attempt to appraise the appropriateness of a freshman's background in secondary-school physics by ascertaining the textbooks from which he studied, to the identification of critical elements in a student's performance in secondary school or on C.E.E.B. examinations, to the development of diagnostic examinations in both physics and mathematics, examinations administered early in Freshman Weekend. It must be emphasized that these efforts have not been undertaken in an attempt to "second guess" the Admissions Office in its decisions, nor have they been used to sort students into rigid categories. We have undertaken, and shall continue our efforts to develop meaningful predictors, because we recognize that the students who enter the Institute as freshmen differ in preparation and interests to a degree that is almost as striking as their extraordinary ability and enthusiasm. We believe that efforts to understand these differences and to apply this understanding with sensitivity and with full recognition both of the limitations of statistical inference and of the rates at which individuals develop, are productive in helping freshmen and their advisors arrive at rational, appropriate first-year programs.

Third and last, we have attempted to minimize the risk associated with an unfortunate choice of academic program. In this regard, the various course programs have been modified in ways that make them more tolerant of variations in the content and timing of first-year programs. Also, efforts have been made to allow changes in a freshman's program during the first half of the fall term more easily and with less curricular penalty.

Freshman Weekend must certainly continue to evolve as the nature of the Institute's undergraduate programs changes and as our entering class changes. Regardless of the detailed nature of these changes, however, it seems necessary that we continue to emphasize academic issues, both in terms of the alternatives open to freshmen and in terms of the factors that should influence a student's selection of program.

COURSE SELECTION Undergraduates are not given an opportunity to specify a choice of course and thus to affiliate with a department until
after they have completed the first year. They are not required to make this choice until the beginning of the third year.

Consequently, all freshmen and many sophomores are engaged, to some degree, in efforts to obtain information on which this selection of course can be based. While some undergraduates have, in effect, made this decision before they enter the Institute, a larger number either defer that decision until they have gained some experience here or find that a decision made earlier is reopened as their horizons expand.

Since its inception 14 years ago, the F.A.C. has attempted to help in this process by presenting a Course Selection Program in the spring term. Although these programs have differed widely in terms of format, they have shared a common set of operational objectives. Specifically, three objectives have characterized these programs:

1. Students have been encouraged to make extensive use of the personal resources open to them — upperclass students, their advisors, and the faculty more generally — as sources of information about disciplines and careers.

2. Questions which are fundamental to the course selection process and which transcend the details of a specific choice have been raised and discussed for the freshmen. For example, questions relating to the role of graduate study, to the opportunities for a later change in direction, and to the continuing adjustment of one's conception of a career have been raised. The vehicle has sometimes been an F.A.C. Newsletter or a letter from the President of the Institute; on other occasions it has been a set of speakers or a panel discussion.

3. The departments have been encouraged to describe their activities and interests to the students, and to provide an introduction to the variety of careers for which their programs are appropriate. In most cases these presentations have taken the form of exhibitions, of open houses, or of a series of lectures.

On the whole, the Course Selection Programs have not been as effective as they should have been. In part this has occurred because the issue of course selection has been emphasized only during a two- or three-week period in the spring term, while the processes of information gathering and decision making normally extend over a much longer period. We intend in the future to direct attention to the issues and the information sources over a much longer period of time — essentially the whole first year — and to rely less on a concentrated period of activity in the spring term.

PAUL E. GRAY
ACADEMIC PERFORMANCE

In terms of probation and disqualification, the Class of 1971 continued the favorable trend of the past few years with still fewer of their number finding themselves in serious academic difficulty at year's end. The figures below further reinforce the presumption that the major curriculum changes first introduced for the Class of 1969 have indeed improved the chances that the individual student will be successful in his transition from high school to M.I.T.

<table>
<thead>
<tr>
<th>Class</th>
<th>Probation in February</th>
<th>Probation in June</th>
<th>Disqualification in June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of 1966-68</td>
<td>51</td>
<td>43</td>
<td>23</td>
</tr>
<tr>
<td>1969</td>
<td>35</td>
<td>41</td>
<td>9</td>
</tr>
<tr>
<td>1970</td>
<td>35</td>
<td>52</td>
<td>8</td>
</tr>
<tr>
<td>1971</td>
<td>28</td>
<td>28</td>
<td>7</td>
</tr>
</tbody>
</table>

CURRICULUM FLEXIBILITY

The basic options available to the Class of 1971 again centered on the first-term alternatives of deferring chemistry, deferring physics, or deferring “nothing” — the label applied to a program including chemistry, humanities, mathematics and physics in the fall term. The recommendation to defer chemistry or physics was made by each student’s advisor, based on the student’s College Board scores and his scores on math and physics diagnostic tests administered during Freshman Weekend. The student was free to make the final decision, and feedback from upperclassmen took on added importance — and complexity — because now two out of every three upperclassmen had been permitted similar options as freshmen.

In his report last year, Professor Gray elaborated on the effects of this feedback and went on to discuss the apparent need for alternative versions of the science core subjects as a means for better encompassing the highly diversified backgrounds of those qualifying for admission. It should be noted here that the Class of 1972 will be the first to benefit from several important changes along these lines. A new two-term sequence in physics has been designed to be more compatible with the recently reduced core requirement in physics than the present four-term sequence. Designed primarily for those whose academic objectives do not require the intensive treatment of the subject now provided by the longer version, the new sequence has the corollary advantage of being ideally suited for those freshmen who may wish to continue in physics but who arrive at M.I.T. with little or no preparation in calculus. Thus
it will no longer be necessary, nor indeed even advisable, for a student to defer physics; rather those who wish ultimately to pursue the more intensive physics will be able to make the transition at the end of either the first or second term as their proficiency in calculus develops. The fact that fewer students than before should think of themselves as "behind" by electing this particular version of physics is expected to increase the probability that an individual freshman will select the alternative more appropriate to his own abilities and preparation.

In another change to promote flexibility, the options available to each student to fulfill the Institute chemistry requirement have been expanded, and greater use will be made of the diagnostic exams in helping freshmen decide on the best timing if they choose the "traditional" subject. By vote of the Faculty this past spring, freshmen may now register for an introductory subject in organic chemistry, for which a good high school chemistry course is good preparation, or for a subject in chemical thermodynamics, which has first-term physics as a prerequisite and second-term calculus as a co-requisite; either of these subjects as well as the traditional freshman chemistry subject will fulfill the basic Institute requirement. The traditional general chemistry subject has undergone change too, such that it now is to the student's benefit to have some advanced exposure to calculus and physics. This change fits in well with the design of the diagnostic tests, the results of which will be used this coming fall to identify those students who would benefit most from taking this option in the spring term.

Less reflective perhaps of differences in preparation, but certainly responsive to the increased awareness today's high school graduates have of social issues and studies in the humanities, per se, the Class of '72 will have five options from which to choose a sequence in humanities, an increase of two more than this year. The titles of each sequence reflect the strength of the humanities and social sciences at M.I.T.: "The Western Tradition"; "Identity and Autobiography"; "Language, Culture, and Community"; "Conflict and Community in America"; "God and Logic"; "The Philosophy of Religion in America."

PASS-FAIL

Undoubtedly the most significant change to affect the next four freshmen classes will be the pass-fail grading experiment proposed by the Committee on Educational Policy and adopted by the Faculty late in the spring term. Under this experiment the only grades to be recorded for freshmen by the Registrar will be Pass (N) or Fail (F), regardless of the subjects taken.
Under Pass-Fail, student performance will continue to be measured by the traditional means of homework sets, quizzes and papers, but in lieu of simple A to F letter grades at the middle and end of term, both the student and then his instructor will attempt a more qualitative, written description of his work. Copies of these reports will go back to the student and to his faculty advisor, whose capability to provide effective and meaningful counsel should be increased measurably. Furthermore, the validity of the important decisions concerning probation and disqualification is almost certain to be enhanced.

Overseeing the experiment and deciding on most matters of policy and procedure that are affected is the ad hoc Committee on Evaluation of Freshman Performance (C.E.F.P.), whose membership is drawn from the Faculty, administration, and student body. Among their earliest actions has been the underscoring of the Faculty's intent that freshmen continue to concentrate their energies on a normal number of subjects, rather than spreading themselves too thin over a larger number. Translated into specifics, 54 units per term is the limit for which a freshman may receive credit; it is hoped that this upper bound will tend to encourage greater student-faculty interaction as the students begin to think of ways in which they can pursue individual subjects in directions and to an extent not covered in the required work.

During the next four years the reports of the Freshman Advisory Council will contain much about the progress of the Pass-Fail experiment, not only because we are involved in the experiment, per se, but also out of the realization that the requirement for effective counseling becomes greater with every such change that provides increasing recognition of the uniqueness of each student. Effective assimilation of a Pass-Fail grading system may well require substantive changes in the nature of the F.A.C., and therefore we look to the experiment as a new source of data for our continuing assessment of the future role of the F.A.C.

PETER BÜTTNER

STUDENT COUNSELING

Students at M.I.T. in 1967-68 did not dig up paving blocks. Nor were their heads battered by night sticks. But national and international events stood massively in the background for all those students who were assessing, thoughtfully, sensitively, and responsibly, their part now and in the future in a technological society. Perhaps only a few M.I.T. students, in reviewing events of the past year, would be reminded of the passage in Acts when the apostle Peter, explaining the events of Pentecost,
VICE PRESIDENT, ACADEMIC ADMINISTRATION

quoted the prophet Joel: “... and your sons and daughters shall prophesy, and your young men shall see visions ... And I will show wonders in the heaven above and signs on the earth beneath, blood, and fire, and vapor of smoke.” But they would understand immediately the sentence in Kenneth Keniston’s book, The Uncommitted, “But let a young man announce his intention of becoming a poet, a visionary, or a dreamer, and the reactions of his family and friends will unmistakably illustrate the values most Americans consider central.”

Students still refer, though less often than a decade ago, to M.I.T. as a “factory.” They are not referring to its physical characteristics. They are referring to the fact that to be successful as a student involves behaving as an efficient cognitive machine whose smooth functioning is not disturbed by feelings. Indirectly they are referring not just to M.I.T. but to the nature of the society they are soon to join as adults. They perceive this society as one that is in constant change. But they wonder whether this change is at the mercy of impersonal technological forces, or whether it can be made to serve the non-technological ends of life, liberty, and the pursuit of happiness. It is not a question of whether to trust anyone over 30; it is a question of whether to trust the universe.

UNDERGRADUATE ACADEMIC PERFORMANCE

Evaluating the academic performance of undergraduates is within the province of the Faculty Committee on Academic Performance. This committee is charged with the final decision of whether a student’s performance is such that he should be placed on academic probation or should be disqualified. But the picture of the academic performance of the student body as a whole is best given, not by noting the relatively small number that are disqualified or placed on probation, but by noting that, according to information supplied by the Registrar, two-thirds of all grades given at the undergraduate level are A’s and B’s, and that the “bottom” quarter of a class has a C average.

In 1968-69, the Chairman of the Committee on Academic Performance will no longer automatically be the Secretary of the Faculty, but will be one of the voting members of the committee.

THE PROBLEM OF DRUGS

Accurate and full information on the use and misuse of drugs at M.I.T. is impossible to obtain. But several impressions are shared by those in a position to gather concrete if incomplete information. During 1967-68, as in the previous year, L.S.D. was not a problem. The potential danger of its use appears to be accepted by the overwhelming majority of M.I.T. students.
DEAN OF STUDENT AFFAIRS

But the use of marijuana appears to be growing more widespread. If its use by students is defined as a problem for which a solution should be found, no such solution is apparent. Strict disciplinary action alone is no solution. Legal action by civil authorities is not providing a solution. Legalization, even if it should occur, would remove only one aspect of the problem. Frank and open discussion is necessary, and competent medical advice is available.

In one sense, the problem is not a Dean’s office problem; it is the students’ problem. But in a more fundamental sense it is a moral problem in which we are all involved. Whether a student does or does not see his decision to use or not to use marijuana as a moral choice, and how he then chooses to act, will be influenced by his perceptions of society. If society, as he sees it, gives only lip service to self restraint, and if he decides to deny himself an experience which others claim is pleasurable and relatively harmless, such a decision will be a mark of his own strength of character, not a mark of respect for, or fear of, society’s standards.

SELECTIVE SERVICE

During the past year Selective Service has been a major source of stress for the M.I.T. community. On June 30, 1967, President Lyndon Johnson issued Executive Order 11360, which created dissonance between Selective Service policy and many educational policies of the Institute. The Order changed many of the ground rules of student deferment and left much uncertainty in its wake.

A further problem developed when, on February 15, 1968, the Selective Service System accepted the recommendation of the National Security Council that all graduate student deferments be ended in June, 1968, with the exception of “medical, dental and allied medical specialities.” Thus, most of our graduating seniors faced great uncertainty regarding their future plans for graduate school, employment, and military service. We have advised them generally to apply to graduate schools as they normally would but we have also apprised them fully of the new policies involving graduate study. In response to these changes, many more of our seniors have applied for jobs in industry which they feel may carry occupational deferments. Many have also applied for combined S.B.-S.M. programs which have a long-standing tradition at M.I.T.

In April, President Howard Johnson appointed an M.I.T. Committee on Selective Service with the responsibility of continuous monitoring of Selective Service law and policy so that it might make recommendations.
for the development of M.I.T.'s policies and advising students and staff. Dean Sanborn C. Brown was appointed Chairman of the Committee and chief liaison officer with Selective Service. The other members of this committee are Malcolm G. Kispert, Dr. Jack P. Ruina, Dean Irwin W. Sizer, Professor Prescott A. Smith, Philip A. Stoddard, Dean Kenneth R. Wadleigh, and Robert K. Weatherall.

On the same date Mrs. Amy Metcalfe took over responsibility for the Undergraduate Selectice Service advising program. Mrs. Eleanor Lutz, the former advisor, has entered a terminal leave of absence until her retirement in June, 1969. She will continue to act as a consultant to the Committee on Selective Service.

WILLIAM SPEER
RICHARD A. SORENSON

THE WOMEN STUDENTS

During the 1968 spring term the number of women students at M.I.T. was 358. Of these, 191 were undergraduates, 167 were graduate students and 26 were exchange students from Wellesley and Radcliffe. The numbers offer a significant contrast to those in effect when McCormick West was dedicated in 1963. At that time there were 103 undergraduate and 128 graduate women. During the intervening years the coeds' contribution and participation in student and community affairs have grown tremendously in both quality and quantity. The election in February of Maria Kivisild '69 as Undergraduate Association President showed clearly that though relatively few in number, the women students are an active and integral part of the community.

The crowning event of the year was the dedication of McCormick East on March 1. The remarks of Dr. James R. Killian and William H. Bemis, long-time legal advisor to Mrs. Stanley (Katherine Dexter) McCormick '04, on that occasion made Mrs. McCormick's life take on new meaning for all concerned with the building and its residents. One wished that Mrs. McCormick could have lived just a few more months to participate in this dedication and to see the beauty of the building and receive the tributes paid her. The success and spirit of the Open House, held soon after the Dedication for the entire community, gave some measure of the part McCormick Hall plays in the atmosphere and quality of life at M.I.T.

The Abby Rockefeller Mauzé Professorship, founded "to enrich the professional lives of women students," was held this past year by two distinguished scholars. In the fall term Dr. Mildred Dresselhaus, a solid-state physicist who has made outstanding contributions in the fields of
superconductivity, band structure of solids and magneto-optical properties of metals, met informally with the students and shared her views and experiences. In the spring term our coeds were fortunate to get to know Dr. Margaret Burbidge. Mrs. Burbidge, a fellow of the Royal Society, is a noted astrophysicist whose major field is spectroscopy. Both Mrs. Dresselhaus and Mrs. Burbidge contributed significantly to the aspirations of the women students.

RESIDENTIAL PROGRAM FOR UNDERGRADUATE WOMEN

As the spring term began, all women undergraduates living on campus were once again under the same roof. “McCormick Annex,” which had first been located in Moore House and then in Westgate, the Institute’s married-student apartments on West Campus, was closed when McCormick East was ready for occupancy. The 30 girls who had lived in Westgate left it and the independence of on-campus apartment living with real regret. Two of the group were seniors who, instead of returning to McCormick Hall, used their option to live off campus. Four juniors who planned to live off campus in their fourth year were not required to return to the dormitory for the single remaining term, but rather were given the opportunity to find suitable living quarters off campus.

Based on one year’s experience, the exemption of seniors from the on-campus residence requirement is successful. Only a handful of the students who were eligible to live off campus actually did so. During the 1968-69 academic year the distribution of undergraduate women on and off campus, relative to the past term, is expected to be the following:

<table>
<thead>
<tr>
<th>Class</th>
<th>McCormick</th>
<th>Off-Campus</th>
<th>McCormick</th>
<th>Off-Campus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>—</td>
<td>—</td>
<td>63</td>
<td>0</td>
</tr>
<tr>
<td>1971</td>
<td>52</td>
<td>0</td>
<td>55</td>
<td>3</td>
</tr>
<tr>
<td>1970</td>
<td>43</td>
<td>6</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>1969</td>
<td>29</td>
<td>15</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td>1968</td>
<td>25</td>
<td>17</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>38*</td>
<td>192</td>
<td>24*</td>
</tr>
</tbody>
</table>

*Eleven are married students

The increased number of women offered admission with the Class of 1972, as shown in the above table, reflects the availability of the added accommodations in McCormick East. Since the total capacity of McCormick Hall is now 221, graduate women are being offered the oppor-
tunity to fill the vacancies for 1968-69. In 1969-70 undergraduates are expected to fill this house.

Special facilities such as the country kitchen, the recreation room and the sewing room in McCormick East receive steady use. The recreation room and, in particular, the sensitive and enthusiastic leadership by Mrs. Joan Blackmer gave a small, somewhat tentative dance group real strength. Use of practice rooms and art facilities is growing. The recreational facilities provide an important balance to academic pressures.

In view of the exceeding comfort in which the women students live, it is almost unreasonable to suggest that they lack for anything. They do, however, need greater access to athletic facilities. This need will become even more acute as the number of women students increases.

THE M.I.T. PREMEDICAL ADVISORY PROGRAM

The Premedical Program has completed its first full year of operation. It has been busy but rewarding in that the quality, idealism, and energy of the students and their dedication to the service of mankind is impressive and exciting.

During the fall a total of 47 students sent applications to 57 medical schools. The Premedical Office collected faculty letters of reference, prepared a commentary on each student, and sent this packet of information to every school on the student’s list. On the average, each student applied to ten schools.

The result of this activity was that 38 of the 47 applicants were accepted for admission to medical school in September, 1968. Circumstances in the backgrounds of those who were not admitted, which made them less competitive applicants, varied widely. In some cases the decision to try for medical school had been made too late to accumulate all necessary prerequisites. In others the desire merely to attend graduate school predominated. Thus some students applied knowing that the medical schools were not likely to grant them admission.

The group of 47 applicants included six graduate students, 39 seniors, and two alumni. Three were women. Their distribution among the M.I.T. majors was as follows:

<table>
<thead>
<tr>
<th>Course</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautics and Astronautics</td>
<td>1</td>
</tr>
<tr>
<td>Biology</td>
<td>23</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>2</td>
</tr>
<tr>
<td>Economics</td>
<td>1</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>8</td>
</tr>
</tbody>
</table>

556
In order to increase M.I.T. students' chances of admission by putting applications in the hands of admissions committees as early as possible, a major effort was made during this spring term to interview all candidates for admission to medical school in September, 1969. Faculty letters of reference will be collected during the summer. This shift of activity made the year extremely busy in the Premedical Advisory Office, but we hope the results should be worth the effort. A total of 48 applicants for September, 1969, had been interviewed by June 30.

Efforts were made throughout the year to communicate with all students considering medicine as a career. The programs sponsored by the undergraduate Premedical Society were very helpful in this respect. In fact the "Premed" Society and its officers, Mark A. Rockoff '69 and Richard D. Kremsdorf '69, have been an integral part of the Advisory Program's activities. Great help has also been contributed by Dr. Jerome Grossman '61, whose office at the Massachusetts General Hospital is always open to students wishing to talk about medical school curricula, research, care, and so on to a young physician with the "M.I.T. point of view."

Interest in medicine and biomedical research is increasing in the M.I.T. student body. In addition, changes in the Selective Service Act have made significant numbers of persons, who would otherwise not have done so, seriously consider medicine as a career. The already keen competition for admission to medical school will thus become even more intense. The Premedical Advisory Office will continue to have busy days!

EMILY L. WICK

FOREIGN STUDY ADVISOR

Official title and job description seldom match as closely as they do in the Foreign Study Advisor. However, the word Advisor is a deceptively simple description of a complex task. In this report I shall describe the character of and principal activities included in this task, based upon my first year's experiences.

In response to the question, "Advisor to whom?" three distinct categories of persons immediately emerge, each quite distinct. The first
are the Junior Year Abroad (jya) undergraduate students. Second are those whose study abroad will be as predoctoral graduate students. The third and rather diverse category is lumped together under the tag, Postdoctoral.

The Advisor's job has some similarities for all three categories. Basically, he serves as a catalyst to stimulate and assist the individual's own self-examination and thinking through of his urge for an educational experience in a foreign scene. What are the real reasons underlying the urge, what are the objectives, and what are the special resources available to satisfy these objectives? What is the "mix" of wanderlust or travel on the one hand, and serious academic work on the other? Each has its legitimate and appropriate role in life, but the formulation of program requires clear identification of motivations and priorities in the student's own mind.

Another characteristic common to most who think of a foreign study experience is unawareness of the possibilities for, and limitations on, opportunities. What opportunities are available and what are the requirements of each? These are so diverse that the Advisor can know specifics on only a few. He can direct the student to the various sources of information bearing on his interests and later discuss his ideas and proposals with him.

Where a foreign language is involved, the high level of competence essential to a good experience has to be explored and emphasized heavily. On this there is universal agreement among all concerned with foreign study. Then there are questions of financing and financial aid, Selective Service, best emphasis in academic program abroad, and adequate discussions with departmental counselors.

A major element common to all categories is the problem of adequate and sufficiently early exposure of potential foreign study candidates to the idea of foreign study. In many cases serious anticipatory action based on fairly clearly formulated general plans is required 15 to 18 months ahead of anticipated departure. How best to reach the relatively few in our total community, from freshmen to faculty, who have potential interest in foreign study is perhaps the major challenge to the Advisor.

Turning now to the peculiarities differing among the three categories, the junior-year-abroad group is most closely involved with the Advisor. This jya program is an internal M.I.T. matter up to the point of formal application by the student to an institution or foreign program with the backing of the Advisor. This program has been of modest size with the following numbers: 1964-65, 1; 1965-66, 3; 1966-67, 9; 1967-68, 4.
Although as yet neither Selective Service nor travel restrictions are actual threats, the present climate of feeling is not encouraging to foreign study and the 1968-69 contingent will probably be less than 10.

I have personally visited supervisors, institutions, and students at Nantes, Paris, and Munich, as well as jya students returned to M.I.T. I have also had good visits exploring possibilities at Imperial College, University of London, and at Sussex University, Brighton. The nature of the possibilities at Sussex is particularly attractive for those qualified to work only in English.

I am persuaded that this jya program yields a total educational experience clearly justifying continued support by the Institute. I also feel that, for the immediate future, the fairly informal person-by-person exploration and development of a unique program for each is the best procedure.

In the predoctoral graduate student category, our principal activity, apart from general counseling and assisting individual exploration of possibilities interesting to each person, is assisting in the application and screening process for several fellowship programs. Of these, the Fulbright-Hays program of the U.S. government is by far the largest in number. However, the Rhodes, Churchill, and Marshall fellowships are notable examples of smaller, but prestigious opportunities on which we give assistance to applicants and sponsors. In addition, there are many other sponsors, foreign and U.S., whose programs justify careful consideration by appropriate applicants. In all this, the Advisor has a direct and personal role with interested students, in addition to working relations with the sponsors, and with the Institute of International Education, which is the operating agent for the U.S. government in the Fulbright-Hays and many foreign source grants.

At the postdoctoral level, the Advisor primarily advises concerning possibilities, sources of information, and procedures, because at this level the applicant usually deals directly as an individual with the sponsor or his agent.

I have emphasized the great variety and diversity of opportunities in foreign study and in sources of information concerning these opportunities. There is comparable diversity in the interests and characteristics of those interested in foreign study at the various levels. Perhaps an Advisor's greatest service is to help the interested individual identify and crystallize his interests, often not as obvious and simple a process as it might seem, and to help him identify and locate those possibilities for experience of the sort he seeks among the myriad programs, agencies, associations and educational institutions on which information is widely scattered.
VICE PRESIDENT, ACADEMIC ADMINISTRATION

Quite appropriately, the Placement Bureau includes in its small working library on future opportunities for students an excellent and continuously updated collection of all materials pertinent to foreign study. With some guidance from the Foreign Study Advisor and the assistance of the person operating the Placement reference collection, the interested student can readily inform himself of the opportunities and ways and means open to him or her.

For the future, continuing effort is needed on the least satisfactorily developed aspect of foreign study, namely more effective ways of making potential benefactors of a foreign study experience aware of the possibilities and opportunities. Once a student’s interest becomes conscious and expressed, the operation, though sometimes complex and cumbersome, is fairly well in hand.

HAROLD L. HAZEN

RELIGIOUS ACTIVITIES

The M.I.T. Chapel has been the setting this past year for 647 scheduled religious services, 14 special services, 31 musical programs, and 1,252 other musical and religious purposes. These numbers represent modest increases compared to a year ago. The Chapel also has been the setting for 114 weddings. The number of weddings, up from 76 a year ago, reflects in part new procedures arranged by the Reverend Harry Dooley to accommodate Roman Catholic weddings. Increases in all aspects of the chapel program are anticipated as we continue to house more students on campus.

In consort with the temper of the times, which has prompted innovation and experimentation in liturgical practice and the style and vocabulary of worship, there has been an increasing frequency of lay participation in all religious services. Special music has been written on occasion by students and performed by students. Additionally, new forms of expression, employing graphics, and the visual and performing arts, are being incorporated in the act of worship. This experimentation undoubtedly will continue, for this mood seeks to bring religious and spiritual meaning into sharper focus at this time, while insisting that worship is a creative act.

Within the broader aspects of the religious program, the several student religious organizations continue to sponsor individual programs while cooperating in events common to each other. The “Interface” meetings, held again this year, have provided weekly opportunities for conversations among students representing the several traditions. The Religious Counselors have sponsored numerous discussion
groups and seminars; and, in the Freshman Weekend period, they combined efforts to present discussions of the topics "Religion and Secular Knowledge" and "Religion and Social Change." A larger portion of the Religious Counselor's time this year has been spent in private conversations with students. Many of these conversations have developed as students have sought them out to examine with them a variety of moral and ethical questions prompted by the exigencies of our time.

Here and at other campuses, new cooperative arrangements are being fashioned by and between a number of the Protestant denominations to coordinate more effectively the plural ministries to students and universities. Presently the United Ministry in Higher Education, an organization formed for this purpose, is coordinating the efforts of some of the denominations represented here. In looking ahead, it is anticipated that additional denominations will enter into this cooperating arrangement.

The Reverend Reginald Smart of the International Ministry, Harvard-M.I.T., will leave at the close of this year to go to a new assignment at Lake Erie College. The Reverend Robert C. Holtzapple will be on study-leave during the year 1968-69.

ROBERT J. HOLDEN

STUDENT GOVERNMENT AND ACTIVITIES

In reviewing and assessing the record of the student activities over the past year, the many operations and agencies of student activities can be grouped under four general headings which denote their source, scope, or administrative responsibility. There are undergraduate activities, undergraduate government, graduate government and community programs. Far from existing within a rigid framework, these groups and their components are in constant change, reflecting the dynamic character of individual students and the student population as a whole, shifts in student interests and concepts of organizations, and the capacity of students for innovation and uniqueness. Programs, meetings, and events, although generated in a wide variety of type and kind, are yet throughout expressions of student concern and initiative. While this wide assortment of activity is based mainly in the community buildings, Kresge Auditorium, the M.I.T. Chapel, the Stratton Student Center, and Walker Memorial, it also requires the limited use of facilities in the academic buildings. As in any community, it is the presence of these voluntary activities that underlines the fact that its residents are vitally active.
VICE PRESIDENT, ACADEMIC ADMINISTRATION

UNDERGRADUATE GOVERNMENT

Early in the fall, the Institute Committee sponsored a student-faculty-administration conference entitled "The M.I.T. Myth." The conference concerned itself first with identifying the preconceptions of M.I.T. that a freshman brings with him, and second with determining the impact an erroneous conception may have upon his student life at M.I.T. In analyzing the impact that M.I.T.'s education, philosophy, and program had upon entering freshmen, it was suggested that an M.I.T. high school for Cambridge children be established, staffed by M.I.T. undergraduate student teachers. Such a teaching opportunity, it was suggested, would alter positively the nature of an M.I.T. educational experience. As a result of this suggestion, steps were taken to allow a number of students to practice teach in a Cambridge high school in order to test the soundness of this concept. Thus this Institute Committee conference, as is true with many other student-faculty exchanges, had a valuable by-product in addition to its desired objectives.

Reflecting a growing concern on the part of students to keep abreast of national and international issues at the same time that they are immersed in an academic community, the Institute Committee redirected some of its efforts to meet these new needs. To help the students to understand extra-university issues better, the Institute Committee developed a lecture program which will gather outstanding public figures to the campus. This program, to start early next fall, will bring men who have espoused challenging ideas, men who have made substantial contributions to society, and men who are simply controversial.

Within the Undergraduate Association, a number of organizational changes were made during the past year. The role and nature of the Freshman Council was altered to allow its members to participate more fully in student government affairs, and to give greater emphasis to matters of educational significance. The responsibilities and duties of the Activities Development Board (A.D.B.), a student-faculty committee, were redefined to meet the changing needs of student activities. A new subcommittee, the Student Committee on Environment, was formed to meet the growing interest of the student body in their environment and to channel constructively both their criticisms and their positive suggestions about the M.I.T. environment. As a direct result of a "Design Your Own Classroom" contest which the committee sponsored, a standard classroom was completely redesigned and refurnished.

This year's Parents Weekend, an every-other-year affair sponsored by the Institute Committee, was marked by a unique informality and
DEAN OF STUDENT AFFAIRS

candor in its efforts to portray what college life, and in particular life at M.I.T., is actually like today. This unique quality was due for the most part to the introduction of seminars both on educational philosophy and on such non-academic questions as activism, student autonomy, drugs, and the Selective Service. These seminars, comprised of student-faculty panels and involving students and their parents, drew the following comment from the Technology Review reporter: "... taken as a whole, it may have been the first time in history that parents, students and faculty have come together for such outspoken exchanges on such thorny issues at the Institute."

Another innovation was the Student-Alumni Weekend, which brought more than 50 alumni, who serve as educational counselors, back to M.I.T. for a two-day series of seminars and informal get-togethers. Each visiting alumnus was the guest of a student host with whom he attended discussions and in whose living group he was a house guest. The weekend gave each alumnus a candid view of M.I.T. and its students of today and gave each student host a new perspective on the professional world he is about to enter.

UNDERGRADUATE ACTIVITIES

To single out the accomplishments of one or two activities would seem to slight the more than 100 other organized student groups, except that these accomplishments are not unique but are in fact representative of the year's total record, to which each of the individual groups has made a singular contribution.

One such accomplishment was this year's edition of the yearbook, Technique. Working with the theme "The Awakening University," Technique presented this year in review not just a superb sequence of photographs, but also a substantial number of essays. These essays dealt with all facets of life at M.I.T.: its educational philosophy, its people, and its environment, and through a variety of individual views of student involvement and contributions highlighted M.I.T.'s past history, its present problems, and its future opportunities.

One of the performing arts groups, the Gilbert and Sullivan Society, was invited to give a performance of Trial by Jury in an actual courtroom, that of Harvard Law School. This performance produced a second invitation from WGBH-TV, the Boston educational station, to videotape in color a performance for broadcast throughout the educational television network.

Still another accomplishment was the successful expansion of the High School Studies Program to include two sessions during the school
year in addition to its established summer session. This program, sponsored by the Technology Community Association, brings bright high school students to M.I.T. for college level classes taught by M.I.T. undergraduates. The program offered 24 courses last summer and had an enrollment of 900. During its first winter session it offered 15 courses and had an enrollment of 600.

Many of this year's accomplishments in some way represent changes in the nature and scope of student activities as determined by the students themselves. No activity is more representative of the new desire of M.I.T. students to be involved both with their own campus community and with the larger community and its concerns than Innisfree. This journal of inquiry, which came into its own this year, published articles which were sometimes complimentary, sometimes critical, but always articulate. Although the magazine covered both Institute and national issues, each issue usually focused upon a particular subject: one was on "The Negro and M.I.T." another on "Vietnam: A Divided Issue." Its Man of the Year was Noam A. Chomsky, teacher, researcher, and political activist.

Last fall, to insure that such accomplishments continue and that the activities themselves grow, the Activities Executive Board developed and sponsored the first integrated activities orientation program for incoming freshmen. The Board published an Activities Handbook which described the nature of extracurricular life at M.I.T. and specifically the kind of opportunities that exist in each of the organizations. During Freshman Weekend, the Board sponsored a discussion seminar on the extracurricular experience and the opportunities available. Later in the fall it held an Activities Open House in the Student Center. As a result of this integrated program, more freshmen joined activities than ever before, with the expected result of increasing activity accomplishments.

GRADUATE GOVERNMENT

The term graduate government refers to the function of the Graduate Student Council, which in serving the graduate population combines both elements of government and of activity sponsorship and coordination.

During the past year, under the leadership of Dean H. Vanderbilt, G-VI and John B. L. Harkness, G-X, the Council increased both the scope and variety of its activities. Shortly after registration day, the Council hosted a dinner for all new foreign graduate students. The number of foreign students in attendance and the variety of nationalities represented generated considerable interest and enthusiasm not only
among the American hosts but also among the new foreign students themselves. Later in the fall, the Council sponsored a series of luncheon meetings of Council representatives with departmental secretaries in order to bring these important women up to date on the activities of the Council.

The Catalyst, the newsletter sponsored by the Council, evolved from a sometime mimeographed letter to a regularly printed magazine. By dealing with both campus and off-campus controversial subjects, the Catalyst generated much interest in the graduate community, and by providing excellent coverage of the affairs of the Council, it came to be necessary reading for all graduate students.

The Graduate Council Lecture Discussions presented Daniel P. Moynihan and Jerome Y. Lettvin. In the spring the Council sponsored a presentation of Riot, a play dealing with civil rights issues produced by the Theatre Workshop, Boston, Inc., and performed by a group of teenage Negroes from the Roxbury area of Boston. The presentation of the play to standing-room-only audiences is indicative of the increased interest on the part of graduate students in social service endeavors.

The Committee on Graduate School Policy invited two observers from the Council to its April meeting. This invitation, the first of its kind, opened the way to a new and challenging opportunity for graduate student-faculty communication. One result of the first such meeting was the establishment of a ruling allowing the Council to place items for discussion on the CGSP agenda. Furthermore, the total agenda will henceforth be available to the Council before the committee meetings, which will permit the Council to discuss the topics in advance and thus enable the two observers to inform the committee of the thoughts and opinions of the entire Council.

COMMUNITY PROGRAMS

In the opening section of this report, Dean Wadleigh has reviewed a number of community programs which resulted from student protest activities, the tragic assassination of Dr. Martin Luther King Jr., and student social service efforts.

In a different vein, the M.I.T. community was presented with a variety of programs in the performing arts. The Department of Humanities cosponsored, with the Lecture Series Committee, an evening of ballet with Edward Villella and Patricia McBride dancing Igor Stravinsky and George Balanchine's Apollo, narrated by B. H. Haggin; the San Francisco Mime Troupe, the theatre of protest; and an off-Broadway play, In Circles. Tech Show '68, I Wed Three Wives, a skillfully con-
received and well-produced original musical comedy, continued in the new trend of Tech Shows which are broadly based comedies rather than solely Institute-oriented shows. The Gilbert and Sullivan Society presented, in its now established pattern of outstanding performances, *Iolanthe* and *Ruddigore*. As noted in the following reports, the community was also treated to excellent performances by each of the musical organizations and by the M.I.T. Dramashop.

The Awards Convocation, which, through the individual awards presented, seems to sum up the year's achievements, this year saw the following receive the William L. Stewart Jr. Awards for contributions to extracurricular life and the Karl Taylor Compton Awards for outstanding contributions in promoting high standards of achievement and good citizenship within the M.I.T. community.

**WILLIAM L. STEWART JR. AWARDS**

Stephen I. Gallant '68, the General Manager of *VooDoo*
For his organizational and editorial efforts at a critical time for our campus humor magazine. He and the magazine have once again successfully proved that we can laugh at ourselves.

Charles F. Manski '70, the Director of T.C.A. High School Studies Program
The T.C.A. High School Studies Program has been, for a number of years, a successful summer program conducted by M.I.T. students. This year it undertook a major step and enlarged the program by offering Saturday classes during the school year. It was ably guided through the critical transition by its director.

Michael J. Marcus '68
For his over-all contributions to student activities through his many and varied public relations endeavors, two of which were "Topics in Technology" and the Central Photography Exhibit in last year's Open House.

Kenneth P. Morse '68
A.I.E.S.E.C. is the student-run foreign student exchange program which arranges for the exchange of summer jobs in industry and government. Under his able leadership the M.I.T. A.I.E.S.E.C. Chapter was revived and was able for its first year to send 11 students abroad on A.I.E.S.E.C. traineeships, and in addition it sponsored a conference on "Housing and Urban Redevelopment" for 40 foreign trainees in the U.S.

John S. Niles '68
For the responsible and conscientious manner in which he has served
the Technology Community Association both as a member and as an officer for four years. As President this year he has given leadership and direction to all of the activities of the association and in the words of a fellow officer, “given the organization a feeling of unity.”

Richard P. Rudy ’68

Although he has ably served as President of the Gilbert and Sullivan Society and as President of the Baton Society, and although they have expanded under his leadership, we will remember him best for his colorful characterizations on the Kresge stage.

Thomas C. Woodruff ’70

As an officer of the Social Service Committee he served with insight and concern as director of Talent Search and Tutoring Plan, he opened new avenues of communication with Harvard’s Phillips Brooks House to deal effectively with common projects and he was a valuable board member of Reach, Inc., a Cambridge educational consortium.

A.S.M.E., accepted by David F. Cahn ’68

Through its seminar and speaker program, this student professional organization has successfully involved students in a continuing dialogue on the ethical and moral issues which surround the engineering professions in today’s society.

The Class of 1971 Freshman Council, accepted by William H. Rastetter ’71

It has sponsored projects which have successfully engaged freshmen in both the academic and extracurricular aspects of Institute life to the betterment of its own class and the class which will arrive next fall.

Innisfree, accepted by James A. Smith ’69.

This journal of inquiry has commented with insight on both the concerns and issues of this educational community and the larger society and on their relationship and relevance.

The Logarhythms, accepted by Albert Harlow ’70; Alan Calavano ’68

These men of song have not only been effective ambassadors of M.I.T. through their concerts for colleges, schools, and community groups; they have also shown their talents as effective producers by their successful presentation of the Log Jam ’68, an evening of delightful entertainment.

Technique ’68, accepted by Steven C. Chamberlain ’69 and Richard M. Koolish ’69

Technique, the annual yearbook, reflects each year the life of this community. This year the book’s theme is “M.I.T.: The Awakening University,” which is developed through more than 70 full-length articles
and essays along with superb photography. This book is a result of the efforts of more than 100 students ably directed by an editorial staff of 20. The Stewart Selection Committee feels that this remarkable level of participation, which led to the production of this superb book, reflects the imagination and involvement for which all our student activities strive.

THE KARL TAYLOR COMPTON PRIZES
Richard Phillip Adelstein '68
Both student and teacher, his inspiring engagement with preparatory education has focused concern for those upward bound.
Ellen Ruth Greenberg '68
A devoted impresario, whose resourcefulness in forging talent has won appreciative audiences.
Karla Sue Hurst '68
Authentic representative, she fostered unbiased regard for personal feelings.
Peter Henri Rittner '68
Poet, essayist, profound inquisitor in the student dialogue on education and social problems.
Alfred Allen Singer '68
Exponent of participation, his clear voice articulated the meaning of involvement in the awakening university.
Stephen Ezra Straus '68
A man of action and perspective in a time of discussion and protest, he has constructively channeled a growing social awareness.
William Burton Zimmerman '68
Skilled craftsman whose creative efforts and leadership have enhanced the performing arts at M.I.T.
East Campus Seminars, accepted by Stephen Roger Kutner '68; Stanley Chang '68
A pacesetting achievement demonstrating that residential programs of substance can evoke a stimulating response.
Social Service Committee, accepted by Thomas Charles Woodruff '70
A sustained coalition establishing points of contact among equals frustrated by cultural isolation.

Since the musical and dramatic activities comprise major sectors within the total extracurricular program, both because they involve a major portion of the student body in their performing groups and
because all performances reach the entire campus through their large audiences, it seems appropriate to report these activities separately. Accordingly, the reports to follow are submitted by Professor Klaus Liepmann, Director of Music; and Professor Joseph Everingham, Director of Drama.

ROBERT J. HOLDEN, JAY C. HAMMERNESS

EXTRACURRICULAR MUSIC

A great many concerts took place at M.I.T. during the last season. They were sponsored by the Department of Humanities as well as by various student organizations and ranged from internationally famous artists to student ensembles.

Groups which performed in the M.I.T. Humanities Series, coordinated by Professor Gregory Tucker, were the Zagreb Pro-Arte String Quartet, the Swiss Tenor Ernst Haefliger, the Zurich Chamber Ensemble, the Chigiano Sextet, and the Hungarian Quartet.

The Kresge Organ Series, coordinated by John Cook, presented three concerts this year. Gillian Weir played works by Bach, Mozart, Dupré, Messiaen and Brahms; Olivier Messiaen and his wife Yvonne Loriod performed Messiaen's *Visions de l'Amen* for two pianos; and E. Power Biggs played an experimental program of music on the Challis pedal harpsichord.

Begun last year as an experiment, the Thursday Noon Hour Concerts in the M.I.T. Chapel enjoyed great success again this year. The program naturally focused on the use of the organ in the Chapel, but they also included instrumental ensembles and vocal performances, and much use was made of the M.I.T. harpsichord. Admission to these concerts was free, and most of the performing was done by music students at M.I.T. and in the Boston area. This series is also coordinated by John Cook.

The Chamber Music at M.I.T. concerts were held in the Sala de Puerto Rico in the Student Center and were directed by Professor Tucker. Artists who performed in these concerts were Elias Lopez, piano; Joan Benson, clavichord; John Buttrick and Louis Moyse in a program of music for four-hand piano by Schubert; the Music Guild Quartet from the Boston Symphony Orchestra; Bruno Hoffman, glass harp; Jean and Kenneth Wentworth in a program of contemporary music for four-hand piano; Denes and Anneliese Zsigmondy, violin and piano; Michael Rudiakov, 'cello; Jan Curtis, mezzo-soprano; Eric Rosenblith and Gregory Tucker, violin and piano; and John Buttrick, piano.
In November the Department of Humanities sponsored a concert of electronic music which was presented by Dr. Fritz Winckel of the Technische Universität Berlin, who was Visiting Professor of Music for the fall term.

The M.I.T. Symphony Orchestra, conducted by Professor David M. Epstein, gave two concerts at M.I.T. this year and during spring vacation had a successful tour, which included concerts at Montclair State College in New Jersey, Earlham College in Indiana, Denison University in Ohio, and George Williams College in Chicago. The first concert by the Orchestra included Brahms' Academic Festival Overture, Beethoven's Symphony No. 1, Stravinsky's Symphonies for Wind Instruments, and de Falla's El Amor Brujo with Eunice Alberts, mezzo-soprano, as soloist. The second program and tour programs included Rossini's "Overture" to The Italians in Algiers, Schoenberg's "Accompaniment Music to a Film Scene," Brahms' Symphony No. 2 and Carl Nielsen's Clarinet Concerto, with Ray Jackendoff as soloist.

Under the direction of Klaus Liepmann, the M.I.T. Glee Club combined with the glee clubs of Mount Holyoke and Sarah Lawrence Colleges in performances of Honegger's King David and Orff's Carmina Burana.

The M.I.T. Choral Society, also under the direction of Klaus Liepmann, gave two concerts this year. In the first concert the Choral Society, assisted by the Cambridge Festival Orchestra and soloists, sang Bach's Cantata No. 63, Cantata No. 191, and the Magnificat in D. In May the Choral Society performed Bruckner's Mass in E Minor, Stravinsky's Symphony of Psalms, and Bartok's Cantata Profana (first performance in the Boston area) with 63 members of the Boston Symphony Orchestra. The group also performed Bruckner's Mass in E Minor at the Mid-Winter Conclave of the American Guild of Organists.

The M.I.T. Concert Band, conducted by John Corley, gave two concerts at M.I.T. Its 17th annual tour included concerts at Bowdoin College in Maine, in Skowhegan, Maine, where the group played a benefit concert for a hospital, in Showinigan, Ontario, and at Loyola College in Montreal. Works included on the tour programs were John Bavicchi's Festival Symphony, which was commissioned by the Concert Band two years ago, Vittorio Gianinni's Symphony No. 3, Richard Hervig's Music for Winds and Percussion, Andrew Kazdin's Prelude and Happy Dance, and Carl Kroeger's Variations on "Chester." In the spring concert at M.I.T. the band played the Symphony Funèbre et Triomphale by Berlioz and Form No. 1 for Band by David Mott, a piece commissioned this year by the Concert Band.
On the more informal side, the Logarhythms delighted many alumni up and down the Atlantic Coast with their good old-fashioned harmonizing, and the Baton Society arranged another successful All Tech Sing, which brought together fraternities, dormitories, and non-resident students in a program ranging from madrigal to barbershop to rock n’ roll.

KLAUS LIEPMANN

EXTRACURRICULAR DRAMA

In the Little Theatre of Kresge Auditorium, under the auspices of the M.I.T. Dramashop, the undergraduate drama program presented two sets of experimental one-act plays for the M.I.T. community during the fall term. New student directors, designers, and actors, under the supervision of the permanent drama staff, produced for two evenings in October, *The Dirty Old Man* by Lewis John Carlino and *Kitchenette*, the first Boston presentation of the new American playwright Ronald Tavel. In early November, a second one-act program of *The Eternal Song* by Marc Arnstein was performed with Jean Cocteau’s fantasy *Orphée*. The one-act evenings were free and the audiences were asked to join in a critique on stage with the student acting company, directors, designers and technicians after each performance.

The Boston premiere performance of *Drums in the Night*, Bertolt Brecht’s earliest full-length anti-war drama, set in Berlin in 1919 during the uprising, was staged by the director of drama and given five performances in mid-December as the major fall production.

The same format of productions was repeated for the spring term audiences. One-act evenings followed by audience critique included *Not Enough Rope* by humorist Elaine May and noted American playwright Edward Albee’s *The Zoo Story* for two performances in February, and in March, Eugene O’Neill’s two-man drama *Hughie* with French playwright Jean Anouilh’s stylish costume comedy *Cecile, or the School for Fathers*.

An adaptation by the director of drama of Ben Jonson’s rowdy Elizabethan comedy, *Epicoene, or the Silent Woman*, was directed by the adapter and given five performances April 25 to May 4.

In addition to its own program of performances, M.I.T. Dramashop jointly sponsored two evenings of modern dance in conjunction with the Dance Circle Company of Boston on May 11 and May 12 in the Little Theatre.

JOSEPH D. EVERINGHAM
In the firm belief that an active interest in sports promotes desirable qualities of character and growth of personality, the Institute traditionally has sponsored a program of athletics for all undergraduates as an integral part of an education at M.I.T. Emphasis has been on regular participation habits by all students rather than arena-based sports spectacles for a few gifted athletes. We believe that life-long recreative interests have a positive influence on career success and a general preparedness to meet the rigors of modern living. At the same time we have encouraged and fostered among our varsity athletes the highest level of individual and team performance in local, regional, and national intercollegiate competitions.

In recent years we have attempted to extend this same philosophy to graduate students and to interested faculty, staff, and employees within the M.I.T. community. The existing limitation of adequate space in highly specialized athletic facilities required to accommodate the entire community has been discussed thoroughly in previous reports. For example, the Alumni Swimming Pool barely meets the needs of approximately 3,800 undergraduates, particularly during the popular late afternoon hours. Yet we continue to attempt adjustments to meet the requests of an M.I.T. community of 15,000 people in addition to token allocations of swimming time for interaction in the Cambridge-Boston community. The traditional swimming pool usage for beginners’ instruction, intercollegiate, and recreational swimming has expanded in recent years to include major interests in water polo, white water sports, scuba instruction and community swim programs. A second swimming pool oriented to the development of the West Campus residential plan is a must if we hope to meet the demands for recreational outlets for all students. The same can be said for additional facilities for tennis and squash, for the replacement of our antiquated ice skating rink and for expanded indoor athletic facilities in general, including related ancillary space for the administration and operation of a program in athletics and recreation commensurate with our objectives.

During the past year the Planning Office and the Athletic Department have collaborated in programming long-range needs for athletic space for the Institute. Special attention has been given to: a proposal which will be practical in terms of land area already available on the West Campus; and a scheme which will permit phasing the total development in stages as funds become available. Presently, we are stalled for lack of funds for preliminary design. I report this as our most urgent need at this time.
DEAN OF STUDENT AFFAIRS

PROGRAM HIGHLIGHTS FOR 1967-68

PHYSICAL EDUCATION

The Physical Education Program provides a broad exposure to athletic interests for all entering men. Professional instruction is offered in sports selected according to the interests of individual students. All freshmen meet desirable standards of swimming proficiency or receive instruction as needed. Similarly, a subject in physical development is offered to those freshmen who score poorly in the self-evaluating 5BX testing program of the Canadian Air Force. The second most popular elective in registration statistics is the subject in development, principally a weight training program.

Following an evaluation of skills in swimming and physical fitness, the student may select a program in freshman athletics or class instruction in the subjects listed below. There were 3,742 registrations in 50 physical education subjects offered in 1967-68, including 605 students who were not interested in credit for physical education. The latter figure includes 171 graduate students, 78 women, 17 staff and 1 alumnus.

INTERCOLLEGIATE ATHLETICS

Increasing numbers of M.I.T. students continue to turn out for the highly disciplined intercollegiate athletic teams. Gymnastics was elevated to varsity status after three seasons of informal club competitions. During the past year approximately 930 undergraduates were active in 490 freshman, junior varsity and varsity contests in 20 sports. A composite record (excludes sailing regattas and ski carnivals) of the varsity teams during 1967-68 includes 144 victories and 101 defeats. Our teams compete favorably without the undue emphasis popularly associated with many intercollegiate athletic programs.

The track and cross-country teams compiled a record of 21 wins against 3 losses during the year. Steve Sydoriak '68 was the New England pole vaulting champion. Ben Wilson '70 set all-time M.I.T. records in the distance events and placed fourth in the National Collegiate College Division Championship 5,000-meter run.

The wrestling team surpassed all records in the history of the sport at M.I.T., winning 12 dual meets against 4 defeats, and placing second in the New England team championships. Individual champions were Jack Maxham '69, Norm Hawkins '69 and Fred Andree '70. Fred Andree went on to win fourth place in the National Collegiate University Division Championship.

M.I.T. hosted the National Collegiate Squash Championships for 1968, placing fourth in the team standings. Highlights of the season were 5-4 wins over Princeton and Dartmouth.
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<td>Tennis</td>
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DEAN OF STUDENT AFFAIRS

The basketball team completed another outstanding season, 16 wins against 9 defeats. David G. Jansson '68, a major in aeronautics and astronautics, was named to the All-American College Division first team. Also, he was awarded one of five scholarships presented by the National Collegiate Athletic Association to outstanding scholar athletes for graduate study.

The baseball team enjoyed the second best season in the 21-year history of the sport at M.I.T. Bruce Wheeler '70 pitched successive wins over Harvard and Boston University. Harvard went on to win the Ivy championship. Bruce was named the most valuable player in the Greater Boston Baseball League.

Other highlights include: Swimmers Luis Clare '69 and Lee Dilley '69 set new M.I.T. records in backstroke and free-style swimming in leading the varsity to a 9-4 season; the gymnasts defeated Yale and Dartmouth, losing only to an experienced Coast Guard Academy team enroute to a 7-1 record in their first year as a varsity sport; the pistol team placed second in the national championships with Dennis Swanson '68 and Ed Busick '68 winning All American honors; the sailing team won the New England Fall Dinghy Championship; and the fencers successfully defended their New England Championship.

Perhaps the most significant highlight is a review of awards presented to those young men who seek out the in-depth participation in varsity sports competitions and the satisfactions that accompany the peak experience in athletics. Awards in the 20 intercollegiate sports in 1967-68: varsity, 253; junior varsity, 83; and freshmen numerals, 282, for a total of 618.

INTRAMURAL ATHLETICS Intramural athletics regularly attract the largest participation of any single aspect of the M.I.T. athletic program. Fraternity and Institute house living groups generally form the nuclei for team organizations and motivate the high morale characteristic of the competitions. In spite of less formal disciplines, the play is keenly competitive.

Intramurals are entirely student administered, including the formation of schedules, training of officials and the handling of all eligibility rules and protests.

An extremely popular trend in recent years has been an option for graduate students to organize separate leagues free of eligibility restrictions, trophies, and other formalities important to undergraduate living groups. A feature of the graduate student basketball league this past year was a playoff with the winners of the Harvard Business School League.
**Participation figures for 1967–68**

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number of Teams</th>
<th>Average Number Players Per Team</th>
<th>Estimated Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Badminton</td>
<td>Singles and Doubles Tournament</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>78</td>
<td>10</td>
<td>780</td>
</tr>
<tr>
<td>Bowling</td>
<td>68</td>
<td>5</td>
<td>390</td>
</tr>
<tr>
<td>Cross-country</td>
<td>28</td>
<td>6</td>
<td>168</td>
</tr>
<tr>
<td>Football, touch</td>
<td>48</td>
<td>17</td>
<td>816</td>
</tr>
<tr>
<td>Golf</td>
<td>39</td>
<td>3</td>
<td>117</td>
</tr>
<tr>
<td>Hockey</td>
<td>34</td>
<td>12</td>
<td>408</td>
</tr>
<tr>
<td>Rifle</td>
<td>30</td>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td>Softball</td>
<td>70</td>
<td>15</td>
<td>1,190</td>
</tr>
<tr>
<td>Squash</td>
<td>56</td>
<td>5</td>
<td>274</td>
</tr>
<tr>
<td>Swimming</td>
<td>22</td>
<td>11</td>
<td>258</td>
</tr>
<tr>
<td>Table tennis</td>
<td>71</td>
<td>3</td>
<td>198</td>
</tr>
<tr>
<td>Tennis</td>
<td>52</td>
<td>7</td>
<td>364</td>
</tr>
<tr>
<td>Track</td>
<td>22</td>
<td>12</td>
<td>264</td>
</tr>
<tr>
<td>Volleyball</td>
<td>94</td>
<td>9</td>
<td>846</td>
</tr>
<tr>
<td>Water polo</td>
<td>28</td>
<td>12</td>
<td>336</td>
</tr>
<tr>
<td>Wrestling</td>
<td>23</td>
<td>7</td>
<td>161</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>763</strong></td>
<td></td>
<td><strong>6,980</strong></td>
</tr>
</tbody>
</table>

In sports like softball, track, water polo, swimming and hockey, the average number of players increased approximately 25 per cent.

**CLUB ATHLETICS**  Closely related to the varsity program in intercollegiate athletics is an area of "club athletics." A club differs from a varsity team in that there are no varsity letters and no eligibility rules generally associated with the intercollegiate competitions. Graduate students and frequently members of the teaching staff join undergraduates in rather informally organized competitions in sports such as rugby, cricket and water polo, for which there is no counterpart among the 20 varsity sports. The Athletic Department assists with facilities as available, and some subsidy for competitions. Professional instruction is provided in specialized activities such as judo. More often, however, the coaching and leadership are provided by the more experienced members of the club.

Typical events among the club sports this past year were: indoor kayak and canoe competitions in the M.I.T. swimming pool as a part of a winter training program, graduate crew club racing among the lesser known rowing colleges in New England, a schedule of eight games for each of two M.I.T. rugby squads, informal cricket on Sunday afternoons during the summer, bicycling competitions at Yale and Cornell, an M.I.T. club competing in a metropolitan badminton league and spring water polo matches in joint scheduling with the Harvard Water Polo Club.
DEAN OF STUDENT AFFAIRS

Clubs active in 1967-68 were:

<table>
<thead>
<tr>
<th>Club</th>
<th>Roster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Badminton</td>
<td>12</td>
</tr>
<tr>
<td>Bicycling</td>
<td>8</td>
</tr>
<tr>
<td>Graduate crew</td>
<td>10</td>
</tr>
<tr>
<td>Graduate gymnastics</td>
<td>15</td>
</tr>
<tr>
<td>Graduate soccer</td>
<td>22</td>
</tr>
<tr>
<td>Hockey — two clubs</td>
<td>28</td>
</tr>
<tr>
<td>Judo</td>
<td>25</td>
</tr>
<tr>
<td>Karate</td>
<td>50</td>
</tr>
<tr>
<td>Rugby — two clubs</td>
<td>30</td>
</tr>
<tr>
<td>Water polo</td>
<td>15</td>
</tr>
<tr>
<td>White water</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>231</strong></td>
</tr>
</tbody>
</table>

ATHLETICS FOR WOMEN AT M.I.T. There continues to be a sizeable group of women who seek regular recreation through athletics. There were 78 registrations in physical education classes in 1967-68, compared to 43 the previous year.

One of the problems in organizing a separate women’s intramural program has been the size of the present enrollment. There simply has not been a sufficient number of women interested in organizing field sports such as lacrosse or field hockey. However, the men’s Intramural Council has invited the Athletic Chairman of McCormick Hall to sit with the Council with the privilege of entering teams in selected individual sports during 1968-68, such as swimming, table tennis, rifle and bowling.

The M.I.T. Women’s Sailing Team won the New England Women’s Intercollegiate Sailing Championship for the second successive year. The fencing team practiced regularly with instruction by Coach Silvio N. Vitale and competed in regular matches among the women’s colleges of Greater Boston. A group of 10 to 12 coeds has been rowing regularly under the guidance of David Waltz, former varsity oarsman. The cheerleaders continue to add color and spirit to our home basketball games.

The most recently organized activity is a very successful dance program with professional instruction by Mrs. Joan D. Blackmer. Elementary and advanced classes are held two evenings and on Saturday mornings. The availability of the new recreation room in McCormick East has increased interest in the dance program among undergraduates.

It is expected that a McCormick Hall student committee will suggest the organization of additional athletics for women in the new recreation room. The Athletic Department is ready to assist with additional sports such as badminton, fencing, and judo, if and when the women request them.
VICE PRESIDENT, ACADEMIC ADMINISTRATION

CASUAL RECREATION The sale of athletic cards generally reflects the interest of the M.I.T. community in the recreational use of the Institute's athletic facilities.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Athletic Card Sales for 1967–68</strong></td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td>5,369</td>
</tr>
<tr>
<td>Faculty/Academic staff</td>
<td>477</td>
</tr>
<tr>
<td>Staff/Employee</td>
<td>1,342</td>
</tr>
<tr>
<td>Alumni</td>
<td>196</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,384</td>
</tr>
<tr>
<td>Sailing Cards</td>
<td>1,414</td>
</tr>
</tbody>
</table>

The above figures reveal that approximately 70 per cent of all students are active in some phase of organized or informal sports. However, the true picture of participation by a large segment of our students, relative to their requests for optimal scheduling, is skewed by the fact that most of our facilities are committed to the formal aspects of the undergraduate program during the popular hours between 4:00 and 7:00 p.m. There are simply no courts available for tennis or squash, except for limited facilities at Walker, during the late afternoon due to commitments to the intercollegiate squads. The same situation exists at all the athletic facilities except the sailing pavilion. I have reported this situation for years, and it continues to worsen with the annual increase in graduate student enrollment and administrative staff. One of the recommended solutions is the inclusion of general exercise areas and facilities for swimming, tennis and squash in the planning of the expanded West Campus residential complex.

Among the most enthusiastic adult athletic groups on campus is a physical fitness class for women conducted at noon Monday through Friday by Mrs. Maggie Lettvin. The group of close to 150 women includes undergraduates, graduate students, faculty, wives of faculty, and secretaries. A visit to the fencing room any noon hour will attest the enthusiasm evidenced by the group and their enjoyment of regular exercise.

Mrs. Joan Blackmer has been conducting classes in modern dance for Matrons and Dames.

A partial listing of additional community recreation programs this past year includes: faculty/staff noon hour volleyball and a fall tennis tournament; tennis instruction during summer evenings, with 240 registrants last summer; sculling at Pierce Boathouse, with 51 qualified during the summer of 1967; 3 teams of faculty/staff competing weekly during the winter months in the Massachusetts Squash Racquets Associa-
tion B, C and D leagues; 1,414 members in the sailing program utilizing our fleet of 51 sailboats; swimming and ice skating instruction for faculty/staff children on Saturday mornings; Family Swim Night on Fridays; Instrumentation Laboratory noon hour softball leagues and graduate student leagues during the twilight hours of the summer season; and a marksmanship program for the M.I.T. Pistol and Rifle Club, Explorer Troop 77, and the 1,209th Research and Development Unit at the Institute.

The Institute's Summer Day Camp continues to attract a capacity enrollment of M.I.T. children between the ages of 6 and 13 during each of the four periods of two weeks' duration. There were 580 camper registrations during the summer of 1967. The popular activities include swimming, sailing, crafts, and sports programs for each age group.

CAMBRIDGE-BOSTON COMMUNITY Except during recess and examination periods, it is virtually impossible to extend the use of the Institute's indoor athletic facilities to the Cambridge-Boston community. An exception has been made at the swimming pool to accommodate the M.I.T. Chapter of Alpha Phi Omega swim instruction program for approximately 160 Cambridge Boy Scouts on Saturday mornings in the spring term. Also, we are experimenting with a plan to permit M.I.T. students in the Tutoring-Plus Program to bring a Cambridge youngster on a one student—one guest basis to any of the athletic facilities during the open hours of the schedule. The usual guest fee is waived and each tutor assumes supervisory responsibility while his guest is on campus.

Throughout the summer months, we have been able to accommodate the recreational needs for two Upward Bound Projects, which included a total of 160 teenagers based at M.I.T. in 1967. Again, however, the swimming pool was the real bottleneck!

With careful scheduling during recess periods and in the fall-spring seasons when our athletic program functions out-of-doors, we have been able to accommodate many worthy community programs in Rockwell Cage and the du Pont Gymnasium. A partial listing of typical events follows: the Boston Globe Science Fair, the New England Amateur Athletic Union and Metropolitan Secondary School Track Championships, the Bay State Wheelchair Games for paraplegics, receptions for the Mayor of Cambridge and the retiring Police Chief, and a Junior Olympic Track Meet sponsored by the Cambridge Jay-Cees.

MAJOR ATHLETIC AWARDS FOR 1967–68
The Class of 1948 Award to the senior “Athlete-of-the-Year”
David G. Jansson '68

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The Admiral Edward L. Cochrane Award to the senior who best combines qualities of leadership, humility, and scholarship in the intercollegiate athletic program
Kenneth F. Wong '68

The Eastern College Athletic Conference Merit Medal to the scholar-athlete of the year
David G. Jansson '68

The Straight T Award, the highest award given for athletic performance at M.I.T.
Frederic W. Andree '70, Norman E. Hawkins '69, Dennis V. Swanson '68, Jeffrey M. Weissman '69, and Ben T. Wilson '70

The Burton R. Anderson Jr. Award to the manager of the year
Kenneth I. Rosenberg '68

The Quadrangle Club Award to the freshman athlete of the year
Co-Winners: Bruce J. Davies '71 and Zdzislaw Maskiewicz '71

The Varsity Club Award to the living group with the most varsity lettermen
Delta Upsilon

The Beaver Key Award to the living group with the highest percentage participation in intercollegiate athletics
Delta Upsilon

ATHLETIC STAFF
New appointments effective July 1, 1967, included: Bruce D. Wright, Instructor in Physical Education and Coach of Gymnastics, R. Kirk Randall, Instructor in Physical Education and Freshman Coach of Squash and Tennis, and Harold Brown Jr., Associate Sailing Master and Coach of Men's Sailing. Stuart A. Nelson was appointed Coach of Women's Sailing.

Professor John G. Barry was appointed Assistant Director of Athletics. Professor Barry will continue to coach Varsity Basketball. Francis C. O'Brien Jr., was appointed Assistant Professor in Physical Education, Assistant Coach of Basketball, and Varsity Baseball Coach.

Peter M. Close, Director of Sports Information, was appointed Director of the Summer Day Camp.

The resignation of E. Vincent Eldred Jr., Instructor and Assistant Basketball Coach, was accepted to enable Mr. Eldred to accept a similar position at Pennsylvania State University.

CONCLUSION
On January 18, 1968, the Corporation Visiting Committee on Student Affairs met with the Athletic Board to review and discuss the long-range needs to upgrade and expand the Institute's athletic plant. I append the
following section of the report of the Visiting Committee dealing with the problems facing the Athletic Department.

From the Report of the 1967-68 Corporation Visiting Committee on Student Affairs:

ATHLETICS

If, within the M.I.T. athletic program, the current practice of encouraging all students to participate in physical recreation is continuous, several vital problems must be faced. The present athletic plant is being used at and beyond capacity; often space is not available to interested groups and individuals. This shortage continues to grow each year, being compounded by the M.I.T. philosophy of athletics; that is, athletics serve an important role in the total educational function; primary emphasis is on individual participation in physical activity and recreation which give the participant a lasting interest.

As the program grows, the demands for added services grow. Graduate students and coeds are becoming more and more involved in athletics, as are faculty and staff. As M.I.T. moves toward a residential campus, there is the tendency for the creation of these demands which again compounds a "healthy" problem.

The Athletic Department and Planning Office are currently involved in an active study of other institutions as well as our own with the intent of developing a clear-cut plan to meet our own future needs. While we stand above our peers in providing programming and participation to all our students, we fall quite short of our peers in facilities and space.

On the basis of considerable joint discussion with the Athletic Board, Dr. Killian, and President Johnson, the Committee arrived at the following conclusions:

1. Facilities for most competitive male intercollegiate athletics are adequate for the present size of the undergraduate male enrollment.

2. No separate athletic facilities should be provided for women students except those of a recreational nature which might be located adjacent to McCormick Hall. Additional facilities to accommodate the women's program should be included in those developed to meet the over-all community need (see 4 and 5).

3. Facilities for intramural and individual recreational sports such as squash, tennis, and swimming, are hard-pressed at the present time, and the latter will be particularly inadequate when more undergraduate and graduate students live on campus.

4. A careful study of the development of graduate student-faculty athletic programs should be undertaken in light of the strong and growing demand in this area. This study should assess the cost and benefits that might be realized if the present facilities were updated to meet these demands. The "total" M.I.T. education for graduate students could be vastly increased if this area were better developed.

5. In view of the increasing number of graduate students whose graduate work is an immediate continuation of their studies, some consideration should be given to the involvement of graduate students in competitive intercollegiate athletics.

6. While additional facilities for individual recreational types of sport, as well as those programs which may be evolved under 4 above, are and increasingly will be needed, they should be so built that all such present and new facilities are available to all members of the M.I.T. community.

7. The Committee does not feel that it has the background to make any suggestion on making M.I.T.'s athletic facilities available to the Cambridge community. It does appear that, for the foreseeable future, it would be very difficult to do so.

ROSS H. SMITH

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During the year 1967-68, M.I.T.'s financial assistance program expanded once again in response to the steadily increasing costs of education. Scholarship and loan awards from all sources to undergraduates totaled $4,192,234 — an increase of 6 per cent over the previous year — and we were once again able to meet fully the demonstrated financial need of every aid applicant. This aid was distributed to 2,170 undergraduates, an increase of 11 students over 1966-67. Table I shows the sources and disposition of these funds.

For the second year, M.I.T. operating funds were used to augment our designated scholarship resources. Awards totaling $317,631 were made from these funds to 288 undergraduates. Scholarship aid from outside sources increased somewhat over the past year. Withdrawal of scholarship support by some corporations and foundations was more than offset by increased gifts by others. The Institute was once again a beneficiary of the U.S. Office of Education's Educational Opportunity Grants Program.

The average award for the year from scholarship and loan combined was $2,050. The average scholarship amount to $1,330 and the average loan was $733.

Another significant increase was evident in the number of loans obtained by our undergraduates from outside sources; 203 students borrowed $241,641, compared with 154 students and $176,267 in 1966-67.

SCHOLARSHIPS

It is again our pleasure to report that our scholarship endowment was increased during the year through the establishment of 12 new funds. Endowed scholarship funds were established by three M.I.T. classes — the Class of 1887, the Class of 1906, and the Class of 1910. Other new funds were the Tenney L. Davis '13 Scholarship Fund for students in chemistry, the Frederick N. Dillon Jr. Scholarship Fund, the Charles Dyer Memorial Scholarship Fund, and the Alton Farrel Scholarship Fund. The Cuthbert C. Hurd Scholarship in Mathematical Sciences, and the Samuel E. Lunden '21 Leadership Grant were established during the year; and the M.I.T. Club of Rochester initiated an endowed fund for scholarships for students from that area. The Institute was also the recipient of a memorial fund established in the name of Gilbert Williams Winslow '37.

In addition to these endowed funds, gift scholarships were established by the Alcoa Foundation, and by the Forging Industry Educational and Research Foundation.
### Undergraduate Scholarships and Loans, 1967-68

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Awards</td>
<td>Total</td>
<td>Number</td>
</tr>
<tr>
<td>From M.I.T. Endowment Funds:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman Scholarships</td>
<td>348</td>
<td>$327,698</td>
<td>348</td>
<td>$327,698</td>
</tr>
<tr>
<td>Upperclass Scholarships</td>
<td>928</td>
<td>1,007,770</td>
<td>928</td>
<td>1,007,770</td>
</tr>
<tr>
<td></td>
<td>$1,335,468</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman Scholarships</td>
<td>71</td>
<td>77,182</td>
<td>71</td>
<td>77,182</td>
</tr>
<tr>
<td>Upperclass Scholarships</td>
<td>217</td>
<td>240,449</td>
<td>217</td>
<td>240,449</td>
</tr>
<tr>
<td>From Outside Sources:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman Scholarships</td>
<td>357</td>
<td>333,883</td>
<td>357</td>
<td>333,883</td>
</tr>
<tr>
<td>Upperclass Scholarships</td>
<td>780</td>
<td>813,179</td>
<td>780</td>
<td>813,179</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,147,062</td>
<td></td>
</tr>
<tr>
<td>Total undergraduate scholarships</td>
<td>2,102</td>
<td>2,800,161</td>
<td>2,102</td>
<td>2,800,161</td>
</tr>
</tbody>
</table>

**Undergraduate Loans — As Awarded**

| From M.I.T. sources:              |        |         |        |        |         |        |        |         |        |        |         |        |
| Freshman loans                    | 762    | 291,979 | 612    | 356,312|        |        |        |        |        |        |         |        |
| Upperclass loans                  | 1,771  | 857,453 | 1,464  | 1,072,959| 1,429,271|        |        |        |        |        |         |        |
| From outside sources:             |        |         |        |        |         |        |        |        |        |        |         |        |
| Freshman loans                    | 89     | 79,316  | 43     | 34,750 |        |        |        |        |        |        |         |        |
| Upperclass loans                  | 163    | 162,325 | 141    | 141,517|        |        |        |        |        |        |         |        |
|                                    |        |         | 241,641 |        |        | 176,267 |        |        |        |        |         |        |

**Undergraduate Loans — Sources**

| Technology Loan Fund               | 1,021  | 352,167 | 1,371  | 780,844|        |        |        |        |        |        |         |        |
| National Defense Student Loans     | 1,054  | 573,353 | 703    | 647,027|        |        |        |        |        |        |         |        |
| Other M.I.T. Loan Funds            | 458    | 223,912 | 2      | 1,400 |        |        |        |        |        |        |         |        |
|                                    |        |         |        |        |        |        |        |        |        |        |         |        |
| Total undergraduate loans          | 1,772  | $1,391,073 | 1,569 | $1,149,432 | 1,788 | $1,605,538 | 1,634 | $1,629,271|        |        |         |        |
| Total scholarship and loans        | 2,170  | $4,191,234 | 1,967 | $3,949,593 | 2,159 | $3,967,569 | 2,005 | $3,791,302|        |        |         |        |
VICE PRESIDENT, ACADEMIC ADMINISTRATION

In all, endowment funds for undergraduate scholarships were increased by $528,724 during the year. Total endowment now stands at $16,057,600, reflecting a 3 per cent increase during the year.

**LOAN FUNDS**

During the year a total of $1,895,314 in loans was granted to 2,232 graduate and undergraduate students (see Table II) from M.I.T.-controlled loan funds. This total represents a decrease of 6 per cent over the previous year's total. Funds allocated for the National Defense Loan Program for 1967-68 increased slightly to $699,033. This increase, together with a substantial increase in the volume of loans made from the several named loan funds administered by the Institute, allowed us to reduce the total number of loans made from the Technology Loan Fund.

The number of students being helped under the Ford Foundation's Forgivable Loan Program for Doctoral Candidates continued to decline as the program approaches completion; 16 students were involved this year, as against 33 last year. The Installment Credit Plan continues to enjoy good use, as 200 students borrowed a total of $127,930 under the plan.

**FACULTY/EMPLOYEE CHILDREN SCHOLARSHIP PLAN**

M.I.T. provides scholarship assistance to children of faculty members who are attending college. In addition, children of faculty members or full-time employees who are enrolled at M.I.T. receive all or part of their tuition, depending on their status. During 1967-68, 27 M.I.T. students received tuition remission of $33,040. Children attending other schools received scholarship aid totaling $185,265.

**JACK H. FRAILEY**

Table II  Loans to Students from all M.I.T. Sources, 1967 and 1968

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Amount</th>
<th>Number of students</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Loan Fund</td>
<td>1,270</td>
<td>$654,894</td>
<td>1,630</td>
<td>$1,070,714</td>
</tr>
<tr>
<td>Other M.I.T. Loan Funds</td>
<td>560</td>
<td>266,917</td>
<td>7</td>
<td>6,500</td>
</tr>
<tr>
<td>National Defense Student Loans</td>
<td>1,220</td>
<td>811,103</td>
<td>807</td>
<td>771,567</td>
</tr>
<tr>
<td>Installment Credit Plan</td>
<td>200</td>
<td>127,930</td>
<td>143</td>
<td>93,409</td>
</tr>
<tr>
<td>Ford Forgivable Loans</td>
<td>16</td>
<td>34,470</td>
<td>33</td>
<td>67,001</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,895,314</strong></td>
<td></td>
<td><strong>2,009,191</strong></td>
<td></td>
</tr>
<tr>
<td>Number of loans</td>
<td>3,266</td>
<td></td>
<td>2,620</td>
<td></td>
</tr>
<tr>
<td>Number of recipients</td>
<td>2,232</td>
<td></td>
<td>2,150</td>
<td></td>
</tr>
</tbody>
</table>

NB: Includes both undergraduate and graduate students.
Statistical data on Admissions Office operations for the year 1967-68, comparable to those presented in previous years, appear below. The figures for the classes entering in September, 1968, are preliminary, and subject to minor revision after the exact counts of registered students have been made in the fall.

TRENDS

Again, this year the trend in undergraduate applications was slightly up — about 3 per cent more completed applications than a year ago. The situation relative to transfer applications remained stable — but with indications that more liberal practices relative to financial aid and campus housing (the transfer applicant is told that he has very low priority for both scholarship grants and housing during his first term here) might increase appreciably the number of good transfer applicants. The graduate application picture is discussed at greater length below.

After several years of gradually increasing yield, the proportion of students admitted who actually expect to matriculate fell off very slightly this year — from 65 per cent for each of the past two years to 64 per cent this year. It is possible that the rise in tuition could have been a factor here; more probably this minor fluctuation reflects the vagaries of the self-selection process, as influenced by a variety of "counseling" measures by other colleges. Our yield is rather high, compared to most of our sister technological institutions; but it is not as high as the yield of our major Ivy League competitors. We are still confronted with the major problem of improving the M.I.T. image: We must make insistent efforts to portray our present qualities more clearly, in prepared statements, in our handling of the selection process, and in our myriad informal contacts with segments of our public.

SPECIAL ITEMS

Three major subjects attracted the special attention of Admissions personnel during the year: the draft, the impact of the race issue on admissions practices, and the special review of policies and practices by the Faculty Committee on Undergraduate Admissions and Student Aid.

THE DRAFT

The Selective Service program has negligible impact on the undergraduate admissions process. The age factor and the virtually unquestioned deferment for undergraduate study leave even the college transfer stu-
### Admissions Office Statistics, 1967–68

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Entrants from secondary schools:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary applications</td>
<td>6,068</td>
<td>6,240</td>
<td>6,414</td>
</tr>
<tr>
<td>Final applications</td>
<td>3,728</td>
<td>3,887</td>
<td>4,218</td>
</tr>
<tr>
<td>Admissions offered</td>
<td>1,423</td>
<td>1,416</td>
<td>1,512</td>
</tr>
<tr>
<td>Actual registrations</td>
<td>922</td>
<td>918</td>
<td>960</td>
</tr>
<tr>
<td>Registrations as per cent of admissions</td>
<td>64.8%</td>
<td>64.8%</td>
<td>63.6%</td>
</tr>
<tr>
<td>Number of secondary schools represented</td>
<td>702</td>
<td>713</td>
<td>744</td>
</tr>
<tr>
<td>Per cent of students from nine northeastern states</td>
<td>47%</td>
<td>53%</td>
<td>47%</td>
</tr>
</tbody>
</table>

**College transfers:**

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total applications</td>
<td>479</td>
<td>497</td>
<td>510</td>
</tr>
<tr>
<td>Applications completed</td>
<td>250</td>
<td>217</td>
<td>235</td>
</tr>
<tr>
<td>Admissions offered</td>
<td>100</td>
<td>85</td>
<td>109</td>
</tr>
<tr>
<td>Actual registrations</td>
<td>75</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>Registration as per cent of admissions</td>
<td>75%</td>
<td>92%</td>
<td>88%</td>
</tr>
</tbody>
</table>

**Graduate students:**

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total applications</td>
<td>5,191</td>
<td>5,462</td>
<td>6,077</td>
</tr>
<tr>
<td>Admissions offered</td>
<td>2,122</td>
<td>2,160</td>
<td>2,255</td>
</tr>
<tr>
<td>Actual registrations</td>
<td>1,218</td>
<td>1,245</td>
<td>1,252</td>
</tr>
<tr>
<td>Registration as per cent of admissions</td>
<td>57%</td>
<td>57%</td>
<td>55%</td>
</tr>
</tbody>
</table>

**Number of personal interviews:**

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>At M.I.T.</td>
<td>1,490</td>
<td>1,514</td>
<td>1,555</td>
</tr>
<tr>
<td>In New York</td>
<td>143</td>
<td>187</td>
<td>204</td>
</tr>
<tr>
<td>By Educational Counselors</td>
<td>—</td>
<td>4,999</td>
<td>5,369</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>6,700</td>
<td>7,128</td>
</tr>
<tr>
<td>Number of persons taking tours of M.I.T.</td>
<td>5,712</td>
<td>5,860</td>
<td>5,552</td>
</tr>
</tbody>
</table>

**Number of secondary schools visited:**

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Educational Counselors (college nights)</td>
<td>117</td>
<td>91</td>
<td>115</td>
</tr>
<tr>
<td>By faculty and administrative staff members</td>
<td>435</td>
<td>239</td>
<td>126</td>
</tr>
<tr>
<td>By Admissions Office staff</td>
<td>255</td>
<td>309</td>
<td>312</td>
</tr>
<tr>
<td>Total</td>
<td>807</td>
<td>639</td>
<td>553</td>
</tr>
</tbody>
</table>

### Advanced Placement

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of students seeking credit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of students receiving credit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of subjects credited</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Procedure:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College Board test program</td>
<td>467</td>
<td>479</td>
<td>367</td>
<td>392</td>
<td>533</td>
<td>579</td>
</tr>
<tr>
<td>Advanced Standing Examinations</td>
<td>21</td>
<td>36</td>
<td>20</td>
<td>36</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>College transcript</td>
<td>47</td>
<td>63</td>
<td>47</td>
<td>61</td>
<td>79</td>
<td>96</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>502*</td>
<td>523*</td>
<td>401*</td>
<td>434*</td>
<td>637</td>
<td>689</td>
</tr>
</tbody>
</table>

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586
ADMISSIONS OFFICE

<table>
<thead>
<tr>
<th>Subjects credited</th>
<th>Number of terms credited</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1965</td>
</tr>
<tr>
<td>Chemistry</td>
<td>114</td>
</tr>
<tr>
<td>Physics</td>
<td>1</td>
</tr>
<tr>
<td>Mathematics</td>
<td>341</td>
</tr>
<tr>
<td>Other specified subjects</td>
<td>5</td>
</tr>
<tr>
<td>Elective Credit (six units each)</td>
<td>94</td>
</tr>
</tbody>
</table>

*In some cases credit was sought and earned through two procedures; duplication is eliminated in the totals.

dents relatively undisturbed. There has been little evidence that factors related to Selective Service have exerted significant influence on the decisions of those who apply for transfer.

On the other hand, changes in Selective Service procedures—notably the decision to discontinue blanket deferments for most types of graduate study—have had profound impact on graduate enrollments at M.I.T. and throughout the country. The situation has been further complicated by some major reductions in Federal funds used in part to subsidize graduate students—notably research assistants. The results have been an increase in the number of graduate student applicants, probably reflecting many more multiple applications; a net increase in the number actually offered admission; and a significant increase in the number who cancelled after having been offered admission.

The number of completed applications was about 8 per cent higher than in 1967, which in turn was a record year. Hedging against the probable effects of the draft, some departments offered admission to more applicants than a year ago; others, restrained by lack of funds for assistantships and fellowships, and in some cases by the abnormally high yields of the previous year, offered many fewer admissions. But cancellations ran significantly higher (as of July 1 they were 40 per cent above 1967); hence, the number of new graduate students expected to register is less than the number for 1967. The net result of these several factors will probably mean a slight decrease in regular graduate student enrollment in the fall of 1968.

THE RACE ISSUE

For several years the Admissions Office has intensified its efforts to obtain more applications from black students. We have made a point of visiting schools with a majority of black students and of inviting many counselors from such schools to our Annual Guidance Conferences. Our cooperation with organizations engaged in special talent searches
has also served to increase the number of applications from black students, but nowhere nearly so much as we would wish. To an appreciable extent, our efforts to attract more students with disadvantaged backgrounds have been offset by the nationwide competition among colleges for well-schooled black students.

Consonant with this recruiting effort has been the practice of applying, within the framework of the normal admissions procedures, highly subjective interpretations of some of the academic measures, where the student's own environment or his school seem to have been disadvantaged. This practice has come into play particularly in reference to the standardized test scores—both the S.A.T.'s and the Achievement Tests. We have been unable to evolve systematic or objective means for adjusting the interpretation of these scores, but we have enrolled students who would have been classed as "risks" on the basis of their C.E.E.B. tests; and they have, with very few exceptions, proven competent to do M.I.T. work alongside fellow students from "better" schools and with much higher scores.

This year, encouraged by these past practices, and influenced strongly by the desire to help out in the racial crisis, we elected to carry on further experimentation. Thus, we have accepted, and expect to register in September, six non-white students who have excellent activities and school records but whose C.E.E.B. scores seem dangerously low by our standards. Confident that a transitional program would be beneficial, we have invited the six to attend, and all but one have elected to attend, a special summer program at M.I.T.

We expect that this group will prove to be competent to perform on a par with other members of the class at M.I.T. We are, however, not sure of their potential, inasmuch as the C.E.E.B. indicators were significantly low for each of these young men. We are, in effect, testing our interpretation of the measurement devices in the belief that the devices, not the students, are inadequate.

Until we collect much more data on interpretation of academic grades and scores, we shall proceed cautiously and fully check our experiments. We are convinced that we must experiment and that this means taking some risks. At the same time, we are very eager to maintain our attrition rate at well below 5 per cent (currently only 1 per cent of the freshmen are disqualified), but we acknowledge that our efforts to be "safe" in this respect would induce us to discriminate against the disadvantaged.

The major objective of the admissions process will continue to be an interesting, academically competent, well-diversified class of freshmen.
We are determined to maintain our long-standing policy of fairness to all applicants; however, we insist that fairness cannot mean standardized application of all the available evaluative criteria.

**COMMITTEE ON UNDERGRADUATE ADMISSIONS AND STUDENT AID**

Under the able leadership of Professor Richard B. Adler, and assisted by Wayne A. Stuart as Staff Secretary, the Committee on Undergraduate Admissions and Student Aid undertook a thoroughgoing review of policies and practices related to freshman admissions and the award of financial aid to freshmen. Weekly meetings were held; many individuals were interviewed at some length; all major steps of the admissions selection process were examined. Special attention was focused on the two primary evaluation factors on which the formal selection is based — the academic prediction and the personal evaluation. Most of the year was devoted to assimilation and evaluation of data. Preliminary findings and conclusions were set forth in a “progress report” at the end of the academic year. No formal report will be forthcoming until sometime in the academic year 1968-69.

The Admissions Office welcomes this full-scale review of its policies and procedures. The Committee seems to be standing back and looking at many aspects of our work with broader perspective, and a more critical viewpoint, than we have succeeded in doing by self-analytical procedures. We look forward to further work with the Committee in the hope that they will be able to articulate some of the Institute’s developing objectives and define policies which should guide the Admissions Office in adjusting its practices to serve more effectively these changing objectives.

Thus far the Committee has not focused attention on such major policy items as those dealing with transfer students or with foreign students. We look forward to having review of these included in their agenda.

**OPERATIONS**

There have been two changes in staff during the past year; Paul E. Johnson resigned to accept appointment as special Assistant to the Vice President and Secretary of the Institute, a promotion richly deserved; William J. Hecht joined the staff as Executive Secretary of the Educational Council and Assistant Director of Admissions, an appointment made in recognition of the increased emphasis we place on the Educational Council’s role in strengthening two-way communications between M.I.T. and the secondary schools. A member of the Class of
1961, Mr. Hecht came back to his new post with an understanding of M.I.T. that equipped him particularly well for his assignment.

Members of the staff continue their interest and participation in general affairs of the M.I.T. community. Mrs. Juanita L. Stuller, Peter D. Leavitt, M. Bryce Leggett, and Peter H. Richardson all served as members of the Freshman Advisory Council. Mr. Leggett completed his fifth year as Executive Officer of the Committee on Academic Performance. Eugene R. Chamberlain continues as Advisor to the M.I.T. Boy Scout Troop; and Mr. Richardson continues as Advisor to the White Water Club. Both Mr. Leavitt and Mr. Richardson have been serving as counselors in the COPE (Center for Opportunity for Progress in Education) program; Mr. Leavitt continues on the Education Committee of the Urban League, and Mr. Richardson on the N.A.A.C.P. (National Association for the Advancement of Colored People) Educational Council. Mrs. Stuller serves as an instructor in Management of Data Systems to the New England Association of College Registrars and Admission Officers.

Mr. Chamberlain has been made President-Elect of the National Association for Foreign Student Affairs, and Robert A. Schuiteman serves on several committees of that organization. The latter is also on the General Committee of World University Service, and on the Ad Hoc Committee on Foreign Students of the College Scholarship Service.

The Admissions Office is indebted again this year to many members of the Faculty and administration for assistance in reading folders, in visiting secondary schools, and in helping host secondary school counselors at the Guidance Conference. We are deeply appreciative of this assistance; but at the same time we believe it to be a highly justified procedure because of the extent to which it informs faculty members of admissions problems and practices. Some 50 individuals read a total of about 2,700 application folders. The following took two or more days (most took a week) from busy schedules to visit schools: Professors Dwight M. B. Baumann, Russel C. Jones, C. Duncan MacRae, Robert W. Mann, Frank E. Perkins, Ronald C. Rosenberg, and John S. Saloma III, along with Kenneth C. Browning and Robert H. Cook, and Financial Aid staff members Peter Büttner, Leonard V. Gallagher, and Daniel T. Langdale.

M.I.T. undergraduate students, notably under the aegis of the student Public Relations Committee, play an increasingly active and effective role as M.I.T. ambassadors, chiefly in their home towns and schools. This aspect of the general Admissions Office program has great potential that must be developed much further than it has in the past.
Similarly, we have made effective use of, and must continue to use, back-stopping support from athletic coaches, musical directors, and other professional leaders of activities. Our policy precludes their initiating contacts with prospective students; it does call for their responding fully, and hopefully enthusiastically, to applicant questions about our activities programs.

One other major group to whom we remain constantly in debt is the Educational Council, report of whose activities is included below. They are indispensable representatives of the Admissions Office.

ROLAND B. GREELEY

EDUCATIONAL COUNCIL

Although Council membership reached 911 this year, administrative efforts were almost exclusively confined to improvement of performance rather than growth in membership. In fact, no more than 10 per cent further growth can be expected as long as administrative resources remain constant.

Significant among the year’s achievements is the fully operational electronic data processing system, which has replaced almost all clerical processing of functions such as personnel, mailing, and statistics. Building on a concept introduced by James H. Eacker in 1961, this system is the result of nearly two years of development with the excellent cooperation of the Office of Institutional Studies. The effect is to expand to 1,000 the capabilities of an office staff that formerly could barely cope with 800 members.

Another inadequate clerical process, referral of admission applicants to the appropriate Council Member, has been automated and will be fully operational in July, 1968. Computer facilities for this operation are being provided by the Department of Civil Engineering.

Better performance of the Council is being achieved by three methods: communications improvement, increased involvement of alumni in the admission and financial aid processes, and decentralization of management responsibilities. Essential to the first two elements has been a major increase in the scope and detail of basic information provided to members of the Council. Some quantitative measure is given by the fact that the Educational Council Handbook, completely rewritten and distributed in September, now contains more than 90 pages of text; more than twice the number of the superseded edition. This has
VICE PRESIDENT, ACADEMIC ADMINISTRATION

prepared our alumni to offer truly valuable and accurate counsel to any secondary school student, applicant or not.

Three-quarters of the Council's membership are within the 100 organized groups located in major population centers throughout the country. The key to improvement of their performance (and to greater economy in Admissions Office public relations) has been increased delegation of management responsibilities to the chairman of each group, as a forceful demonstration that we expect much more than applicant interviewing. The best example to date of such local accomplishment is the arrangement, by the Northern New Jersey Council groups, of a five-day lecture tour for Dwight M. B. Baumann, Associate Professor of Mechanical Engineering, during which he spoke to a total of some 4,000 high school students and teachers.

The distribution of "M.I.T. Science Reporter" films continued this year, with demand exceeding supply. Seventeen films were in circulation, reaching approximately 7,000 students.

William J. Hecht '61 was welcomed to the Council staff in October as Executive Secretary and Assistant Director of Admissions. We now have more than double our previous capacity for person-to-person communications with alumni and we expect to be able to visit all organized Council groups at least once a year. This is an important increment; there is no equivalent for personal contact in the management of a volunteer activity.

Perhaps the most significant aspect of the year has been a marked increase in the spirit of the Council. Gratifying examples of this have ranged from large intensive discussions of the Institute's responsibility to disadvantaged students during the San Francisco Alumni Officers' Conference to enthusiastic individual reports of gains in good will for M.I.T. at specific high schools. The growth of this self-reinforcing enthusiasm is a predictor of steadily improving performance of the Council and of greater strength for the Institute. Now that this spirit has begun to blossom, its cultivation becomes an even more important challenge to the Council staff.

WILLIAM H. MC TIGUE

FOREIGN STUDENT OFFICE

The United States is going through a period of costly turmoil at home, combined with many costly commitments abroad. This difficult period through which we are passing is deeply affecting educational plans and programs, domestic as well as international. This country, however, con-
FOREIGN STUDENT OFFICE

continues to attract an ever increasing number of people from abroad who wish to study in its many institutions, public and private. The Institute of International Education reported that during the 1966-67 academic year there were some 110,000 foreign students and faculty associated with about 1,800 U.S. universities and colleges. Conversely, it is reported that about 30,000 U.S. students and faculty were studying abroad. It is projected that by the mid-1970’s approximately 200,000 persons will be engaged in educational exchange between the United States and the rest of the world.

M.I.T. continues to rank about third among the universities and colleges in this country with the highest percentage of foreign student enrollment. The trends in this mixture of men and women are reflected in the report which follows.

Between July 1, 1967, and June 30, 1968, 24,844 individual pieces of mail were received by the Admissions Office directly related to foreign student applications or to inquiries about the possibilities for admission. This represents an increase of 19 per cent over the previous year. During the same period, we received 6,184 formal applications from foreign citizens, an increase of nearly 44 per cent over the previous year.

FOREIGN STUDENT PROFILE

In the year 1967-68 there were 1,134 foreign citizens enrolled at the Institute; of these 844 were graduate students (21.7 per cent of the graduate population), and 290 were undergraduate students (7.5 per cent of the undergraduate population). They were citizens of 78 different countries. Forty were women students; 339 were accompanied by spouses. The largest nationality group was from Canada (174), followed by India (101), China (98), and Hong Kong (52). The countries of the Far East represented the largest segment of the population (354), with Europe (280), North America (174), Latin America (145), the Near and Middle East (108), Africa and Oceania (64) following in that order. Nine were listed as “stateless.” The group of foreign citizens represented 14.6 per cent of the total student population of 7,730. This count represents all non-citizen students enrolled at the Institute irrespective of their visa classifications. It includes, for the first time, all permanent-resident aliens holding immigrant visas. (In the academic year 1957-58 there were 743 foreign students enrolled at the Institute. They represented about 12 per cent of the total student body. They were citizens of 68 different countries.)

Listed below are some further dimensions of this growing segment of the student body.

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VICE PRESIDENT, ACADEMIC ADMINISTRATION

Degree objectives of foreign students at M.I.T.

Bachelor of Science               205
Master of Science                 307
Engineer                          38
Doctor of Philosophy              320
Doctor of Science                 86
Bachelor of Architecture (Special Students)  (93)

School enrollment of foreign students

Undesignated                      62
Architecture                      58
Engineering                       580
Humanities and Social Science     74
Management                        92
Science                           257

VISA STATUS

Most foreign students enter the United States under the Student visa (F-1) while a much smaller number enter under the Exchange Visitor visa (J-1). Still others enter on Permanent-Resident visas. A few hold Diplomatic (A) visas, or visas as representatives of international organizations (G). Visas held by M.I.T. students are as follows: F-1, 713; J-1, 194; Immigrant, 179; A-G, 53.

FINANCIAL SUPPORT

Foreign students, in increasing numbers, are seeking not only admission to U.S. institutions, but are coupling such requests with urgent pleas for full or partial financial support to cover tuition and maintenance expenses. There are foreign government-imposed restrictions on the convertibility of local currencies into dollars (notably in India) that make it increasingly difficult, if not impossible, for students, particularly undergraduates, to export funds to the United States to meet their educational costs. A number of countries limit the funds a student may convert to cover tuition plus a small maintenance allowance.

Given this situation, it is interesting to know the sources of financial support of those foreign students enrolled at M.I.T. There are 527 graduates and 109 undergraduates, or 57 per cent of the foreign population, receiving financial aid from the Institute in one form or another. Five hundred forty of these receive their principal source of support from M.I.T. Three hundred forty-eight (31 per cent) are financed principally by their own or family funds, while a total of 494 are receiving some support from personal sources.

Home governments support, in whole or in part, 87 (7.6 per cent) of their students enrolled at M.I.T. The United States government, through
a variety of agencies and programs, contributes to the support of 90 (7.9 per cent) of the enrolled student population. Forty-five students hold round-trip travel grants under the Fulbright program. Sixty-five (5.7 per cent) are assisted by foundations and/or industries in the United States. Foreign foundations, industries, and educational institutions support 85 (7.5 per cent) students.

Combining all United States sources of financial support indicates that 791 receive substantial assistance from United States-based sources, while 185 students receive financial aid from foreign or international sources.

FOREIGN FRESHMEN

M.I.T. continues to attract a small but very able segment of secondary school students abroad, particularly from areas that lack excellent scientific and technological universities, or have too few places in existing universities.

For September, 1967, 218 completed applications were received; 48 were offered admission; 31 accepted the offer and registered. Of those coming, 12 were from the Far East, seven from Europe, six from Latin America, five from the Middle East and one from Australia. They received financial support from the following sources: family, twenty; own government, two; M.I.T. scholarship and loan, plus family, three; M.I.T. scholarship and loan, one. At the end of the year, the foreign freshmen averaged 4.0 on our grading scale as compared to 3.8 for the rest of the class. Ten of the students performed above 4.5; two performed below 3.0; none were disqualified.

The foreign applicants are intercompared and selected by a process which is essentially similar to that used for American secondary school students. The relevant factors are secondary school grades, position in class, teachers' evaluations, College Board scores, and non-academic activities. A special Test of English as a Foreign Language is also required.

FOREIGN COLLEGE TRANSFERS

For the term beginning September, 1967, 111 students categorized as foreign completed a final application for admission with advanced standing. More than two-thirds of these students were attending foreign institutions of higher learning. Thirty were offered admission and 22 registered. The geographical distribution of the 22 who were admitted and registered is as follows: nine from the Far East; five from Europe; four from South America; three from the Middle East; one from Oceania.
The majority (13) of the registered group were totally self-supporting or financed by their parents. Four were the recipients of financial aid from M.I.T. The remainder were sponsored by the U.S. and/or foreign governments and agencies. At the end of the second term 12 students had a 4.0 or better cumulative average. All but two achieved a 3.0 or better average for the academic year. One withdrew during the first term because of family illness.

In early January, the Institute joined forces with 165 universities and colleges in the United States as a participating member of the Latin American Scholarship Program of American Universities (LASPAU). This program is designed to meet one of the most pressing needs of Latin America — the preparation of full-time faculty for its schools and universities. College transfer-level students from the lower economic and social classes are nominated by the 107 participating Latin American universities, tested, personally interviewed, and selected by a team of admissions officers. The Institute is free to accept or reject candidates. Admitted students, who have signed an agreement to return to their sponsoring universities as faculty members, receive maintenance funds from the United States government, tuition from the host institution, and borrow the cost of round-trip transportation. The student, provided he makes satisfactory progress, may remain in the United States for a total of four years, enabling him to acquire the Bachelor's and Master's degrees. At present, we have two LASPAU students on the campus. Dr. Julius A. Stratton has made a sum of money available from the Loomis Account in support of our LASPAU students.

THE M.I.T. HOST FAMILY PROGRAM
Since 1961, when this voluntary program was initiated under the leadership of Mrs. Norman J. Padelford, nearly 600 foreign students have been offered hospitality by families in metropolitan Boston. Single students, as well as married couples, have been hosted by families, more than half of whom are alumni of M.I.T. During the 1967-68 academic year about 300 families were active in this program.

Mrs. Glenn Eichenseer acted as coordinating chairman during the temporary absence of Mrs. Padelford. Mrs. Nolan T. Jones, Mrs. Robert Swartz and Mrs. Sidney Williams assisted in the many details associated with the operation of the program.

DAMES
An unusually successful International Night program, held in February, was sponsored by the Technology Dames. This was under the direction
FOREIGN STUDENT OFFICE

of Mrs. George T. Will. Nearly 30 countries were represented by colorful exhibits.

OPERATIONS

Eugene R. Chamberlain, Advisor to Foreign Students, was elected Vice President and President-elect of the National Association for Foreign Student Affairs (N.A.F.S.A.). His one-year term as President starts April 30, 1969. He is Chairman of the National Conference of N.A.S.F.A. to be held in Boston in April, 1969.

Peter D. Leavitt, Associate Advisor to Foreign Students, served as Chairman of the Admissions Section of N.A.S.F.A. in New England.

Robert A. Schuiteman, Associate Advisor to Foreign Students, is Chairman of the Personnel/Job Registry Committee, member of the Government Liaison Committee, the Committee on Nominations and Elections, and the U.S. Students Abroad Committee of the National Association for Foreign Student Affairs. He is continuing as a member of the General Committee of World University Service.

The chief preoccupations of the Foreign Student Office are admissions and counseling. The former requires a substantial amount of time on the part of each officer and member of the staff. While a large percentage of the work is routine, there are questions raised by prospective students from abroad that are complex and require a considered reply. Much of the counseling may be of a personal nature, but is often directly related to the academic welfare of the student involved. There is a heavy load of legal problems, chiefly concerning immigration regulations. The cooperation that is given by the staff to these many and varied activities is greatly appreciated by the Advisor.

There continues to be a close relationship between the Office of the Dean of Student Affairs and the Office of the Foreign Student Advisor in coordinating activities for students in general and, specifically, for those relating to the citizens of foreign countries on the campus. We have been particularly pleased to have the activities of the Foreign Student Office reviewed by the Corporation Committee on Student Environment, and welcome their recommendations and assistance in defining the role this office plays in Institute affairs.

EUGENE R. CHAMBERLAIN
All statistics on registration and staff in the following tables are given as of the fifth week of the Fall Term, except: 1943–44 as of August 2, 1943, 1944–45 as of November 27, 1944; and 1945–46 as of July 30, 1945. For statistics not listed in the following pages, see the report of the Registrar for 1958–59.

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* From 1943 to 1946 Army and Navy students are omitted (see Table 3-B in reports for 1943 to 1946).
### Table I-A  Student Registration in the Summer Session since 1948

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* Students attending regular subjects from M.I.T. curricula.
† Students attending professional and technical subjects which are not part of M.I.T. curricula and in general carry no academic credit.
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* Full professors, associate professors, and assistant professors include 20 professors, 5 associate professors, and 1 assistant professor emeriti part-time active. The total faculty is 974.

1 Includes guests, visiting scientists, visiting social scientists, visiting engineers, research affiliates, postdoctoral associates, and fellows.

2 Includes Institute lecturers.

3 Total teaching staff is 1646.

4 One faculty and 208 non-faculty.


6 Not included in preceding total.

7 Includes two emeriti part-time active.
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**Grand Total:**

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* These totals include the fifth year in Architecture.

1 Prior to 1966-67 Course IV-B.

2 Prior to 1966-67 Industrial Management.
Table III-A. Women Students Classified by Schools, Courses, and Years, 1967–68

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1 Included also in Table 3.
### Table III-B. Special Students Classified by Schools, Courses, and Years, 1967–68

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<tr>
<td><strong>Continued Students</strong></td>
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<td>Undergraduate and graduate students registered at the end of the last academic year (including Special Students)</td>
</tr>
<tr>
<td><strong>Non-continued Students</strong></td>
</tr>
<tr>
<td>Former undergraduate and graduate students who previously attended the Institute but were not registered at the end of the last academic year (including Special Students)</td>
</tr>
<tr>
<td>Undergraduate students who enrolled for the first time since secondary school (excluding Special Students)</td>
</tr>
<tr>
<td>Undergraduate students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding Special Students)</td>
</tr>
<tr>
<td>Graduate students who enrolled for the first time at the Institute (excluding Special Students)</td>
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<td>Special Undergraduate and Graduate Students with no previous Institute registration</td>
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<table>
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<th>Entered Graduate School with Bachelor's degree from M.I.T.</th>
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</table>

| Undesignated      | 2                             | ---                                           | ---                                           | ---                                           |
| First Year        | 8                             | ---                                           | ---                                           | ---                                           |
| **Grand Total**   | **197**                       | **15**                                        | **2,577**                                     | **767**                                       |
## VICE PRESIDENT, ACADEMIC ADMINISTRATION

### Table VI. List of Colleges and Universities with Number of Graduates Entering the Institute as Regular Graduate Students, 1967–1968

<table>
<thead>
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<th>United States</th>
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<td>Akron, University of</td>
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<td>Alaska, University of</td>
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<tr>
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<td>Amherst College</td>
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<td>Antioch College</td>
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<tr>
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<td>Chicago, University of</td>
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VICE PRESIDENT, ACADEMIC ADMINISTRATION

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1 Graduates of 185 Colleges and Universities in the United States and 117 Foreign Colleges entered the Institute.

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| Grand Total                        | 3,857     | 3,873 |

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### Table IX. Number of Degrees of Bachelor of Science Awarded

All statistics on degrees are arranged by school as of the current year. During the years 1868-1949 the general divisions were Architecture, Engineering, and Science. In 1950 the School of Humanities and Social Studies was established and in 1951 the School of Industrial Management (after 1963, the Alfred P. Sloan School of Management) was added.

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<th>Calendar year since 1963 (included in decade total)</th>
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<td>Civil Engineering</td>
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<td>Electrical Engineering (including II-A)</td>
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614
## Alfred P. Sloan School of Management\(^6\)

### Business and Engineering Administration Management\(^5\)

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## School of Science

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### Earth Sciences\(^8\)

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### Mathematics

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### Grand Total

|       | 29 | 226 | 507 | 1,579 | 2,257 | 2,963 | 5,410 | 4,515 | 6,626 | 7,535 | 6,285 | 37,932 | 810 | 771 | 805 | 794 | 867 | 695 |

---

* Includes only February and June degrees.

† Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917.

‡ See also Table XI.

§ Prior to 1923 degrees were awarded in Architecture.

¶ Prior to 1909 this Course was designated as Option 3 (Electrochemistry) of Physics.

‡‡ Prior to 1938 these degrees were included in Mining Engineering and Metallurgy, changed to Metallurgy and Materials Science, January, 1968.

‡§ Prior to 1958 these degrees were included in General Engineering and General Science or General Course.

‡‖ Changed to Alfred P. Sloan School of Management after 1963.

‡∥ Changed to Life Sciences beginning January, 1962.

‡‡ Changed to Earth Sciences beginning February, 1961.

‡‡‡ Prior to September, 1965, these degrees were included in Economics, Politics and Engineering or Science.

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### Alfred P. Sloan School of Management

#### Management

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---

* Includes only February and June degrees.
1 See also Table XI.
2 Prior to 1923 degrees were awarded in Architecture.
3 Prior to 1959 included in Chemical Engineering.
4 Prior to September, 1964, included in Economics, Politics and Engineering or Science.
5 Considered Engineering until 1950.
6 Changed to Nutrition and Food Science in 1962 and changed to Nutritional Biochemistry and Metabolism June, 1967.
7 Considered Engineering until 1956.
8 Prior to September 1965 these degrees were included in Economics, Politics, and Engineering or Science.
10 Includes 6 degrees in Political Science awarded in 1965.
### Table XI. Number of Degrees of Bachelor and Master in Architecture and Bachelor and Master in City Planning Awarded

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* Includes only February and June degrees.
** From 1935 to 1944, Bachelor of Architecture in City Planning.
Table XII. Number of Degrees of Engineer Awarded

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<td><strong>142</strong></td>
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* Includes only February and June degrees.
¹ Prior to 1960 Aeronautical Engineer.
² Degree discontinued after July, 1955.
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<tr>
<td>Grand Total</td>
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* Includes only February and June degrees.
** Prior to 1960 Aeronautical Engineering.
† Previously included in Industrial Economics.
1 Changed from Industrial Economics to Economics in 1966.
2 Changed from Industrial Management to Management February, 1967.
3 Includes Ceramics.
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<td>5</td>
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<td><strong>178</strong></td>
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<td><strong>683</strong></td>
<td><strong>698</strong></td>
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<td><strong>103</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>93</strong></td>
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</table>

**School of Science**

| Chemistry                                        | —       | 2       | 5       | 4       | 3       | 14          | —    | —    | —    | —    | —     | —     | —    |
| Geology and Geophysics                           | 1       | 2       | 4       | 5       | 2       | 1           | 15   | —    | —    | —    | 1     | —     | —    |
| Mathematics                                      | —       | 2       | 3       | —       | 1       | 1           | 7    | 1    | —    | —    | —     | —     | —    |
| Meteorology                                      | —       | —       | 6       | 25      | 17      | 2           | 50   | 1    | —    | —    | —     | 1     | —    |
| Nutrition and Food Science                       | —       | —       | —       | 3       | 10      | 12          | 25   | 2    | 2    | 3    | 4     | 1     | —    |
| Oceanography                                     | —       | —       | —       | —       | 1       | 1           | —    | —    | —    | —    | 1     | —     | —    |
| Physics                                          | —       | 5       | 18      | 14      | 7       | 6           | 50   | 1    | 2    | 2    | 1     | —     | —    |
| **Total**                                        | **1**   | **11**  | **36**  | **51**  | **40**  | **23**      | **162** | **2**  | **3**  | **5**  | **6**  | **6**  | **1** |

**Grand Total**

| 7       | 72      | 214     | 364     | 723     | 721     | 2,101       | 89   | 106  | 105  | 106  | 99    | 49    |

* Includes only February and June degrees.

¹ Prior to 1960 Aeronautical Engineering.
² Including Ceramics.
MEDICAL DEPARTMENT

Table XV. Summary of Degrees Awarded (1868–1968)

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<th>Degree</th>
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<tr>
<td>Grand Total</td>
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</tr>
</tbody>
</table>

* See the 1959 Report of the Registrar for details.

WARREN D. WELLS

MEDICAL DEPARTMENT

The steady increase in utilization of the Medical Department, which was interrupted last year coincident with a nationwide reduction in incidence of respiratory disease, resumed this year with a 7 per cent rise in clinic visits. Fortunately, there were no major epidemics during the year.

As mentioned in last year's report, the Homberg Memorial Infirmary has been accredited for Medicare and Medicaid. In April, 1968, we were informed by the Bureau of Hospital Facilities that in order to maintain eligibility for Medicaid, it will be necessary to be accredited by the Joint Commission on the Accreditation of Hospitals. As a first step in this procedure, we have applied for registration by the American Hospital Association. They will conduct a survey of the Infirmary and, if it conforms to their standards, it will be registered as a hospital. We may then apply for a survey for accreditation by the Joint Commission. While this procedure is cumbersome, it is vital that we maintain our eligibility for Medicare and Medicaid reimbursement. Furthermore, it is probable that Blue Cross-Blue Shield and the commercial health insurance companies will follow the government lead and also require accreditation by the Joint Commission. The health insurance companies are beginning to explore the feasibility of offering comprehensive medical care programs, and it is quite likely that within a few years, a large part of the Medical Department income will be derived from third party payment for both inpatient and outpatient care.

623
Shortage of space is a recurrent theme in these reports. We will need additional room next year because of increased patient load. We are now using all the space in Building 11. In last year's report, the possible use of the Sancta Maria Hospital for our inpatient facility was mentioned. This is still under consideration, but since such a separation of our facilities is undesirable, the M.I.T. administration is studying the feasibility of transferring other activities to the Sancta Maria and releasing space adjoining Building 11 for Medical Department use.

Dr. John W. Chamberlain, Surgeon-in-Chief of the Medical Department for many years, has resigned as of July 1, 1968, to become Director of the Emergency Surgical Service at the Children's Hospital Medical Center. Dr. Chamberlain graduated from M.I.T. in 1928 and from Harvard Medical School in 1932. He has been a member of the Medical Department for 31 years. His departure is a great loss to the M.I.T. community. He is a kind, dedicated and skillful surgeon. He has provided inspiring leadership for the Surgical Service. The members of the Medical Department are grateful that they had the privilege of working with him.

We are fortunate that Dr. John V. Pikula, who is now Associate Surgeon-in-Chief, has agreed to accept the position of Surgeon-in-Chief. Dr. Pikula will continue to serve as Assistant Director of the Harvard Surgical Service and Sears Surgical Laboratory at the Boston City Hospital.

Mrs. Bertha C. O'Sullivan, R.N., who has been Head Nurse of the Homberg Infirmary for 15 years, retires on July 1, 1968. She has managed her responsibilities with great warmth and skill and we shall miss her very much. Fortunately, Miss Mary L. Diehl, R.N., B.S., M.S., Mrs. O'Sullivan's niece, has accepted the position as Director of Nurses for the Medical Department, so the family will continue with us.

Dr. Warren Point, an internist with particular interest in gastroenterology and Dr. Alfred J. R. Koumans, a psychiatrist, joined our full-time staff this year. Other appointments during the year were the following: Dr. Menelaos A. Aliapoulios, Assistant Surgeon; Dr. Harry Y. Azadian, Assistant Surgeon; Dr. Herbert Benson, Assistant Physician; Dr. Donald E. Butterfield, Assistant Surgeon; Dr. F. Gregory Curtin Jr., Assistant Surgeon; Dr. Carola B. Eisenberg, Associate Psychiatrist; Dr. Edward F. Goodman, Associate Ophthalmologist; Dr. Winslow W. C. Green, Assistant Surgeon; Dr. John W. Harvey, Radiation Protection Chemist; Dr. Donald G. Keamy, Assistant Otolaryngologist; Dr. Alexander Levine, Assistant Ophthalmologist; Dr. Howard D. McIntyre, Neurologist; Dr. Arthur J. Neiterman, Assistant Physician; Dr. Donald H. Osterberg, Neurologist; Dr. Gloria A. Rudisch, Assistant
Physician; Dr. Robert C. Runyon, Orthopedic Surgeon; Dr. Duncan P. Thomas, Assistant Physician; and Dr. Helen D. Wallach, Associate Psychiatrist.

Resignations from the staff were submitted by: Dr. Howard A. Blazar, Associate Ophthalmologist; Dr. A. Greer Edwards Jr., Assistant Otolaryngologist; Dr. Stanley A. Forwand, Assistant Physician; Dr. John W. Harvey, Radiation Protection Chemist; Dr. Martin Lubin, Consultant in Biophysics; Dr. William F. McNeely, Associate Physician; Dr. Bernard E. O'Brien, Assistant Surgeon; Dr. James J. Sidd, Assistant Physician; and Dr. James H. Townsend, Physician.

CLINICS

With figures for the final month incomplete, it is estimated that the number of visits to the outpatient clinics will approach 56,900, an increase of more than 3,700 (7 per cent) compared with the previous year (Table I). Most of the clinics shared in the increase, with Medical Clinic visits increased 4.7 per cent, surgical visits up 2.7 per cent and psychiatric visits up 16 per cent. As an example of the potential use of expanded facilities, the Department enlarged its Gynecological Clinic to meet apparent needs and saw an increase in visits of more than 160 per cent.

All segments of the M.I.T. community, with the exception of the Faculty, contributed to the increase in visits to the Medical Department (Table I). Particularly notable was the increase of more than 12 per cent in visits by employees, since they probably are the group least able to receive comprehensive health care outside the Institute.

Table I

<table>
<thead>
<tr>
<th>Clinic Visits</th>
<th>July 1, 1966-June 30, 1967</th>
<th>July 1, 1967-June 30, 1968 (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>20,530</td>
<td>21,500</td>
</tr>
<tr>
<td>Surgical</td>
<td>11,161</td>
<td>11,470</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>2,938</td>
<td>3,400</td>
</tr>
<tr>
<td>Other</td>
<td>18,524</td>
<td>20,530</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53,153</strong></td>
<td><strong>56,900</strong></td>
</tr>
<tr>
<td>Faculty</td>
<td>3,533</td>
<td>3,380</td>
</tr>
<tr>
<td>Staff</td>
<td>5,603</td>
<td>6,220</td>
</tr>
<tr>
<td>Students</td>
<td>28,390</td>
<td>29,260</td>
</tr>
<tr>
<td>Student wives</td>
<td>4,109</td>
<td>4,870</td>
</tr>
<tr>
<td>Employees</td>
<td>10,848</td>
<td>12,200</td>
</tr>
<tr>
<td>Other</td>
<td>670</td>
<td>970</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53,153</strong></td>
<td><strong>56,900</strong></td>
</tr>
</tbody>
</table>
The Prenatal and Obstetrical Program for student wives at the Boston Lying-In Hospital continues to be popular. Ninety-seven student wives are currently enrolled in this program. In March, 1968, the Boston Lying-In Hospital found that it had to increase the student fee from $295.00 to $400.00 and we are informed that the actual cost has risen to about $500.00. We are grateful that the Hospital is willing to continue this program, as it assures our student wives excellent obstetrical care at minimum cost.

We still have no program for pediatric care for student children, though we hope to arrange such a program with the Harvard Pediatric Unit at the Cambridge City Hospital when their new building is completed.

There were 243 athletic injuries serious enough to come to the attention of the Medical Department, a slight increase over last year. As usual, touch football leads the list with 64 injuries, including two fractures and four dislocations. Even though the students made an effort to discipline the game with better refereeing, the number and severity of injuries showed no change from last year. The nature of the injuries and the sports in which they occurred are presented in Table II.

<table>
<thead>
<tr>
<th>Sports</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>64</td>
</tr>
<tr>
<td>Basketball</td>
<td>33</td>
</tr>
<tr>
<td>Hockey</td>
<td>31</td>
</tr>
<tr>
<td>Baseball</td>
<td>11</td>
</tr>
<tr>
<td>Softball</td>
<td>12</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>7</td>
</tr>
<tr>
<td>Soccer</td>
<td>3</td>
</tr>
<tr>
<td>Wrestling</td>
<td>1</td>
</tr>
<tr>
<td>Swimming</td>
<td>1</td>
</tr>
<tr>
<td>Rugby</td>
<td>1</td>
</tr>
<tr>
<td>Squash</td>
<td>6</td>
</tr>
<tr>
<td>Skating</td>
<td>2</td>
</tr>
<tr>
<td>Skiing</td>
<td>3</td>
</tr>
<tr>
<td>Track</td>
<td>1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injuries</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprains and strains</td>
<td>81</td>
</tr>
<tr>
<td>Contusions and abrasions</td>
<td>63</td>
</tr>
<tr>
<td>Lacerations</td>
<td>55</td>
</tr>
<tr>
<td>Fractures</td>
<td>13</td>
</tr>
<tr>
<td>Dislocations</td>
<td>18</td>
</tr>
<tr>
<td>Concussions</td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

A record of motorcycle and scooter accidents has been kept for several years. While the number of accidents has varied little, those involving scooters have decreased strikingly. This year, there was only one scooter injury, but 37 students suffered motorcycle injuries. While most of the injuries were comparatively minor, one student died of his injuries.
MEDICAL DEPARTMENT

DENTAL SERVICE
The number of visits to the Dental Service was 3,829 and represents no change from the previous year. The Dental Service is limited to dental hygiene and diagnosis. As in the past, about two-thirds of the visits were by students or student wives.

HEALTH SURVEYS
Voluntary medical examinations offered to the faculty and to senior members of the D.S.R. staff continue to be popular. A total of 883 such examinations were performed during the year. About 75 per cent of the faculty members and eligible D.S.R. personnel participated. We are continuing our policy of recommending annual examinations for persons over 40 and biennial examinations for younger persons unless they have a health problem requiring more frequent observation.

STAFF AND EMPLOYEE HEALTH PROGRAM
Last year’s striking increase in activity in this area has not been sustained. The reduction is small, however, and the number of examinations done still exceeds that of the previous year (1965-1966) by 614 (about 24 per cent).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-employment</td>
<td>1364</td>
<td>1405</td>
</tr>
<tr>
<td>Women under 30 years old</td>
<td>689</td>
<td>767</td>
</tr>
<tr>
<td>Retirement</td>
<td>92</td>
<td>82</td>
</tr>
<tr>
<td>Hazardous Occupation</td>
<td>102</td>
<td>79</td>
</tr>
<tr>
<td>Employee Health Survey</td>
<td>194</td>
<td>206</td>
</tr>
<tr>
<td>Baseline</td>
<td>108</td>
<td>95</td>
</tr>
<tr>
<td>Others</td>
<td>644</td>
<td>682</td>
</tr>
<tr>
<td>Total</td>
<td>3,193</td>
<td>3,316</td>
</tr>
</tbody>
</table>

PRE-EMPLOYMENT
The anticipated increase in this category did not occur. This probably represents current difficulties in finding people to fill the available jobs.

Among those examined, 15 applicants were found to have conditions which disqualified them for the work they sought. Cardiovascular disease was the commonest cause of rejection (6). Other problems included cancer, emphysema, glaucoma with progressive loss of vision, hernia and such seemingly trivial faults as diminished hearing (in a telephone operator) and color blindness (in a driver). The rejection rate remains fairly constant at about 0.7 per cent.

People with health problems are, of course, employed at M.I.T. if the demands of the work and the capability of the applicant match.
This year, there were 52 applicants for employment who were found to have conditions which, although important, did not disqualify them for the particular job they wanted.

Among the health problems discovered were the following:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal chest X-ray</td>
<td>10</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9</td>
</tr>
<tr>
<td>Diabetes</td>
<td>7</td>
</tr>
<tr>
<td>Deafness</td>
<td>5</td>
</tr>
<tr>
<td>Seizure disorders</td>
<td>5</td>
</tr>
<tr>
<td>Heart disease</td>
<td>5</td>
</tr>
<tr>
<td>Abnormal chest X-ray (Three sarcoid; two inactive tuberculosis)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>9</td>
</tr>
<tr>
<td>Diabetes</td>
<td>7</td>
</tr>
<tr>
<td>Deafness</td>
<td>5</td>
</tr>
<tr>
<td>Seizure disorders (One post-operative brain tumor)</td>
<td></td>
</tr>
<tr>
<td>Heart disease</td>
<td>5</td>
</tr>
</tbody>
</table>

Also encountered were asthma, anemia, cirrhosis of liver with portocaval shunt, emphysema, hypersplenism, hyperthyroidism, emotional illness, multiple sclerosis, chronic renal disease, ulcerative colitis and the Stein-Leventhal syndrome.

Of the 52 new employees with health problems, 21 are being followed in the Medical Department.

**RETIREMENT**

Unfortunately, retirement for medical reasons had to be recommended for three employees. In recent years, no such retirements have been necessary.

**HAZARDOUS OCCUPATION**

The number was greater than last year because, by chance, it includes a greater proportion of the younger employees who are examined biennially.

**EMPLOYEE HEALTH SURVEY**

All employees at the Institute are invited to have a health survey examination when they reach age 45, 50, 55, 60 and 63. This year, 502 invitations were sent and 194 employees accepted (38.65 per cent). This is below last year's all time high of 46 per cent, although only 12 fewer examinations were done.

The results of these examinations are confidential and disclosed only to the patient and his own physician. Among conditions discovered this year were active tuberculosis, previously unknown diabetes, breast mass, hypertension and renal disease.

**BASELINE**

Women under 30 who complete one year of employment at M.I.T. (about half of those who start work here) are invited to have a health survey examination to establish a baseline medical record. This year, 378 invitations were sent and 108 young women accepted the invitation.
OTHERS

The large majority of examinations in this category were done at the patients' own request.

DEATHS

There were 34 deaths of members of the Institute community recorded this year. Heart disease (20), cancer (5) and stroke (6) — the common triad — accounted for the great majority of fatalities. The three other deaths were caused by accidents.

PSYCHIATRIC SERVICE

The Psychiatric Service has had a very significant increase in both the total number of individuals seen and the total number of visits (Table III). The greatest increase in the use of the Service occurred among undergraduates in the sophomore, junior and senior years. It is of interest that 31 students from 18 foreign countries consulted the Psychiatric Service this year. This represents a significant shift over the past few years from the time when few foreign students made use of this Service.

There was a moderate increase in the number of members of the M.I.T. community referred for outside clinic or private psychiatric treatment; however, the proportion referred remained unchanged. Twenty-one patients were hospitalized, of whom nine were undergraduates and five were graduate students. There was one suicide, but the individual was not a student.

During the year, in connection with a Master's thesis in Social Work, Mrs. Donna Pressman surveyed a stratified sample of students to determine their attitudes toward the various helping resources available to them here at M.I.T. The students stated that their primary concerns were in the following order: academic problems, questions concerning their own psychological social identity, sexual issues, career problems, draft problems, and finally interpersonal difficulties, usually with roommates and close friends. They primarily turned to their faculty and to the Deans for help with academic problems, but also included the Psychiatric Service as a relevant facility. Identity problems were most characteristically resolved by themselves or in discussion with friends, though again the Psychiatric Service was frequently noted as a resource to which they would take such a concern if they could not work it out themselves. The sexual issues were primarily dealt with within the peer culture, though ultimately the Psychiatric Service or the Medical Clinic might be consulted. Career problems were usually taken to the Deans and the faculty, but occasionally to the Psychiatric Service.
Table III Psychiatric Service July 1, 1967-June 30, 1968

<table>
<thead>
<tr>
<th>Total individuals seen:</th>
<th>1,022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of visits:</td>
<td>3,497</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis of caseload:</th>
<th>Number of patients seen</th>
<th>Size of class</th>
<th>Percentage of class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total undergraduates</td>
<td>463</td>
<td>3857</td>
<td>12.0%</td>
</tr>
<tr>
<td>Freshman</td>
<td>70</td>
<td>928</td>
<td>7.5%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>146</td>
<td>963</td>
<td>15.2%</td>
</tr>
<tr>
<td>Junior</td>
<td>124</td>
<td>973</td>
<td>12.7%</td>
</tr>
<tr>
<td>Senior</td>
<td>123</td>
<td>993</td>
<td>12.4%</td>
</tr>
<tr>
<td>Uncertain status</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduates</td>
<td>188</td>
<td>3873</td>
<td>4.8%</td>
</tr>
<tr>
<td>Faculty, staff, employees</td>
<td>192</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>126</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of new patients</th>
<th>Total number of patients</th>
<th>Percentage seen for first time this year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduates</td>
<td>313</td>
<td>463</td>
</tr>
<tr>
<td>Graduates</td>
<td>121</td>
<td>188</td>
</tr>
<tr>
<td>Faculty, staff, employees</td>
<td>131</td>
<td>192</td>
</tr>
<tr>
<td>Other</td>
<td>103</td>
<td>126</td>
</tr>
</tbody>
</table>

Number of patients hospitalized

<table>
<thead>
<tr>
<th>Total number</th>
<th>21 (this includes 2 readmissions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduates</td>
<td>9</td>
</tr>
<tr>
<td>Graduates</td>
<td>5</td>
</tr>
<tr>
<td>Faculty, staff, employees</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

Number of patients referred on

<table>
<thead>
<tr>
<th>Total number</th>
<th>122</th>
</tr>
</thead>
<tbody>
<tr>
<td>To clinic</td>
<td>34</td>
</tr>
<tr>
<td>To private doctor</td>
<td>88</td>
</tr>
</tbody>
</table>

Note: The figures given above refer to the period July 1, 1967, to June 7, 1968, (three weeks less than a full year) with the exception of the first two lines, which include an estimate for the period June 8, 1968 to June 30, 1968, and therefore cover a full year.

students tried to solve draft and interpersonal problems themselves, but turned to the Deans or to the Psychiatric Service if further help was needed.

An important theme that emerged from this study was that the students' expectations about the Psychiatric Service were colored by their previous experience or by that of a friend. Only moderate concern was expressed about the problem of confidentiality. In summary, the stu-
dents emerge as essentially pragmatic problem solvers, with a high degree of self-reliance, who prefer the M.I.T. helping facilities to outside sources, particularly with respect to the Medical Department and the Psychiatric Service.

SOCIAL WORK SERVICE
Two hundred new clients consulted the Service during the year. There were also a number of clients being followed for specific reasons who were carried over from the previous year. Among the latter group were several student families and employees with whom a sustaining relationship proved beneficial. The number of visits to the Service increased by 33 per cent.

Referrals come from a variety of sources throughout the Institute. It is of interest that this year, a number of people close to M.I.T., though not actual members of the community, used the Service; for example, two mothers of students, the family of a prospective September admission, a number of girl friends of students in serious difficulty, and several children of employees.

Two blind students were followed closely. Special arrangements had to be made in cooperation with others at the Institute to insure their survival as students. Another blind boy will be admitted in September.

There were a fair number of problems resulting from illness. There were four requests from students for help in meeting extraordinary medical expenses for which no insurance coverage was available.

A number of people presented with problems associated with termination or brought about by retirement used the Service. Through the joint efforts of the Medical Department and the Personnel Office, a 39-year-old employee with a wife and two children, who was on the brink of termination because of a record of absenteeism of 120 days last year, was able to resume a normal working schedule.

Clients consult the Social Work Service for various reasons. Chief among them are concerns of a personal nature, family problems, marital problems, or problems with children. Some clients need help in utilizing community resources. An important function of the Service is to maintain contact with appropriate community agencies on behalf of M.I.T. persons.

INFIRMARY
Admissions to the Infirmary have increased modestly in the past year. With figures for June, 1968, incomplete, it is estimated that the number of admissions for this year will approximate 660, an increase of 5 per cent from last year (Table IV). Both medical and psychiatric admis-
Table IV

<table>
<thead>
<tr>
<th></th>
<th>July 1, 1966- June 30, 1967</th>
<th>July 1, 1967- June 30, 1968 (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infirmary admissions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical</td>
<td>472</td>
<td>495</td>
</tr>
<tr>
<td>Surgical and orthopedic</td>
<td>134</td>
<td>135</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>626</strong></td>
<td><strong>660</strong></td>
</tr>
</tbody>
</table>

| Emergency clinic        |                             |                                        |
| Medical                 | 1,595                       | 1,800                                  |
| Surgical and orthopedic | 1,853                       | 1,860                                  |
| Psychiatric             | 27                          | 40                                     |
| **Total**               | **3,475**                   | **3,700**                              |

Admissions were increased, while surgical and orthopedic admissions were unchanged.

The emergency clinic, offering outpatient services in the Infirmary, had an increased number of visits similar to the clinic experience (Table IV). Medical visits were up nearly 13 per cent, reflecting the recognized increase in frequency of acute infectious illness during the past year compared with the previous year.

There were 450 operating room procedures, 27 more than performed in the previous year. There were only six major operative procedures, all excision of a pilonidal sinus. It is becoming increasingly difficult to obtain the services of a competent anesthesiologist, so that it is quite possible that performance of operations requiring a spinal anesthesia will have to be discontinued.

Malignant neoplasm was encountered nine times. Six of the lesions were basal cell carcinomas, one was squamous cell carcinoma, one Hodgkin's disease and one lymphosarcoma. The specimen in the last case was a lymph node which was removed from the right arm of a patient known to have had lymphosarcoma and was the only evidence of persistence of the disease at the time.

Of the minor surgical procedures, suture of a laceration was the commonest, accounting for one-fourth of all the procedures. Excision of a pigmented nevus was done 62 times, hydrocortone injection 30 times, and incision and drainage 20 times.
MEDICAL DEPARTMENT

One hundred forty-seven specimens removed from skin and subcutaneous tissue were submitted for microscopic examination, most of them to the Pathology Department at the Mount Auburn Hospital.

ELECTROCARDIOGRAPHIC LABORATORY

There were 1,445 electrocardiograms taken during the year, a slight increase over the previous year.

X-RAY DEPARTMENT

The number of X-rays taken was 10,945, a few less than last year because of the reduction in pre-employment chest X-rays.

CLINICAL LABORATORY

The clinical laboratory service continues to be supplied by the Commonwealth Clinical Laboratory on a contract basis. Two technicians are assigned full-time to the small laboratory in the Medical Department and do the routine hematology and urinalyses. The bacteriology and biochemistry are sent to the parent laboratory in Boston. A total of 24,337 laboratory procedures were performed, an increase of 4 per cent.

OCCUPATIONAL MEDICAL SERVICE

The activity of this Service, which is supervised by Dr. Harriet L. Hardy, Assistant Medical Director, continues to increase as the growth of the Institute demands more radiation protection and industrial hygiene support. Dr. Hardy and Samuel Levin, Radiation Protection Officer, or Richard I. Chamberlin, Industrial Hygiene Officer, represent the Medical Department on the various committees concerned with safety at the Institute. While the Occupational Medical Service has the responsibility for the supervision of radiation safety and industrial hygiene safety, it reports its findings and recommendations to the appropriate faculty committee and thus acts as an advisory rather than as a regulatory agency.

The following reports on the Industrial Hygiene Office (I.H.O.) and the Radiation Protection Office (R.P.O.) were prepared by Mr. Chamberlin and Mr. Levin, respectively.

INDUSTRIAL HYGIENE OFFICE

Routine operations continued as in the past, and again the requests for our basic services have increased. It has also been possible to expand the scope of these activities. An outline of the routine service work is as follows:

1. Advice on toxicity of materials.
2. Ventilation surveys and advice on proper control ventilation. This phase of the work continues to expand, and during the past year the various new locations occupied by Instrumentation Laboratory groups have required considerable assistance in design of proper ventilation systems. The fact that we are now advised by Physical Plant on all renovations has also made it possible for us to evaluate and advise on control ventilation when this is included in changes to be made.

3. Hood survey and labeling program. All hoods are surveyed at least once a year, and those where extremely toxic or radioactive materials are handled are surveyed on a quarterly basis. The surveys have been expanded to include complete details on the entire ventilating system, including fan performance data.

4. Evaluation of potential exposures. This is accomplished by analysis of air and biological materials for various toxic materials. This year we have extended the urinalysis program to include the personnel in the Department of Chemistry who are working with organic mercurials. We continue to collect and analyze air samples for the various areas at the Instrumentation Laboratory where work with beryllium is performed.

5. Recommendations for control of contaminants.

6. On-site supervision of filter changing operations. Hood systems for which filtration is provided are included in our quarterly hood surveys. Records of filter performance are made, and by use of manual dampers, total airflow is maintained for the life of the filter. The program is now set up so the departments involved have a second set of stand-by filters to minimize "down time" when actual change is required.

7. Institute Respirator Program. This program has now been extended to include positive pressure respiratory equipment. Success of the overall program is apparent; complete cooperation has been extended by the M.I.T. Purchasing and Laboratory Supply Offices.

8. General. The liaison between our group and other M.I.T. departments is very good. We are now, by cooperation with Physical Plant, involved in the first stages of discussion relative to the proposed new building for the Department of Electrical Engineering. As part of this work, the Occupational Medical Service prepared a questionnaire for circulation to various groups in the Department of Electrical Engineering, to assist all concerned in determining what special controls or equipment should be considered for the building.

The laboratory hood specifications and performance testing procedures developed by I.H.O. were, as previously reported, included in the specifications for the new chemistry building. This year we were invited to evaluate and supervise the performance testing of hoods proposed.
by two major manufacturers who submitted bids for this work. The choice was made based essentially on satisfactory compliance with the tests prescribed.

The I.H.O. group investigated the explosion that occurred on the fourth floor of Building 4. The staff also stipulated the restrictions required during clean-up, and supervised the operations.

Special projects undertaken included the following:
1. The I.H.O. Laboratory continued to analyze biological samples in association with the Beryllium Case Registry. Analytical procedures for this work are being revised and improved constantly in an effort to reduce the size of sample required. Several biopsy samples of lymph nodes have been of special interest; fairly high concentrations have been detected in very small samples.

2. Lead Project. The laboratory analyzes all samples obtained as part of this project. Samples included were blood, soil, water, food, paints, toys, and plaster. This year an effort has been made to study the environment and determine sources of exposure for the children suffering from lead poisoning. Several outside agencies, including the Fernald School, Boston City Hospital, Massachusetts General Hospital, Children's Hospital, and the Boston City Department of Public Health, have cooperated. Actual home visits to investigate sources of poisoning are conducted jointly with the City of Boston Health Department. Meetings have also been held with these groups to outline the basic program we are conducting and to discuss lead poisoning in general.

Soil samples obtained from various areas near urban and rural highways have been analyzed as an initial step in determining whether lead from automotive sources contributes significantly to air pollution.

3. Atomic absorption techniques for detecting toxic materials in biological samples are being investigated. To date, procedures have been developed for lead, zinc, iron, cadmium, calcium, gold, manganese, copper, cobalt, and nickel.

4. Hood development. Considerable time was spent in developing the design and control criteria for laboratory hoods needed for a new area at Lincoln Laboratory. This particular group required hoods for work with toxic materials within a laboratory where "clean room" restrictions must also be complied with. The main laboratory is to be essentially a vertical laminar flow room and the (ceiling to floor) velocity across the entire room will be 100 linear feet per minute. Design criteria were developed to overcome the interferences produced by the laminar flow in the room.

5. Future projects. We would like to undertake additional hood and
filter development programs. There is a real need for this work, as evidenced by the requests we receive for assistance on special problems. However, to do the applied research properly, we are in dire need of adequate space. Ceiling height has been a real limiting factor in this work. The space needed is 300 to 400 square feet with a minimum ceiling height of 12 feet.

Other activities were:
1. Teaching. As previously reported, the staff continues to give lectures and laboratory demonstrations to the students from the Harvard Environmental Health Center.
   At the request of the Department of Civil Engineering, lectures were given to the graduate students.
2. I.H.O. personnel continue to serve on the M.I.T. Laboratory Hazards Committee.
3. The staff are engaged as both officers and committee members for the New England American Industrial Hygiene Association.
4. The staff also serve as advisors to the Boston Poison Control Center.
5. The staff have served on review committees investigating serious explosions in the Boston area.

RADIATION PROTECTION OFFICE

Routine operations of the past year included:
1. The major effort of the Radiation Protection Office continues to be its program for providing advisory and operational services directed towards assisting the various departments and laboratories in maintaining adequate control of radiation hazards, and assisting the M.I.T. Radiation Protection Committee in meeting its responsibilities for ensuring the Institute's compliance with Atomic Energy Commission (AEC) and other governmental regulations that apply to the control of radiation hazards.

   The principal R.P.O. services continue to be as follows: reviewing proposed uses of radiation sources and evaluating potential hazards; providing advice on laboratory design, and radiation protection equipment, methods, and procedures; registration and instruction of radiation workers; personnel monitoring of radiation exposure (film badge program, bioassay and in vivo measurements); laboratory inspections and radiation surveys (depending on potential hazards, these are done on a daily, weekly, monthly or yearly basis); radioactive waste collection and disposal; calibration and repair of radiation protection instruments; environmental monitoring, to measure air concentrations and external radiation; leak testing of sealed radioactive sources; monitoring of in-
MEDICAL DEPARTMENT

coming and outgoing shipments of radioactive material; supervision of radiation emergencies and special decontamination operations; operation of a vehicle for transportation of radioactive material; and compiling and maintaining the radiation protection records required for M.I.T.'s radiation protection program, and for compliance with governmental regulations.

With reference to the above listing, following is a summary of the approximate number of radioisotope laboratories and radiation producing installations that received periodic R.P.O. services during the past year and previous year:

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Radioisotope laboratories</td>
<td>270</td>
<td>230</td>
</tr>
<tr>
<td>Particle accelerators</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>X-ray machines</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>Laser units</td>
<td>120</td>
<td>150</td>
</tr>
<tr>
<td>Microwave units</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

As of June 10, 1968, there were approximately 900 persons registered with the Radiation Protection Office for work associated with the use of sources or equipment that emit ionizing radiation. In addition, there are approximately 430 persons listed with R.P.O. for work involving potential exposure to laser and microwave radiation.

The radioactive waste disposal program followed its established course during the year. Increases were noted in all types of waste handled. The walk-in freezer for animal carcasses, installed in Building 20 last year, is used continually, and increased quantities of animal waste are being sent to the Harvard incinerator. During the year, three shipments of solid radioactive waste, involving a total of 2,300 cubic feet of material, were packaged and shipped to an AEC-licensed burial site.

2. Operation of the Central Radioisotope Laboratory and Storage Facility. The use of the Facility by research personnel decreased during the 1967-68 period. Nine departments used the Facility for a total of 426 man-hours, compared to 652 man-hours of use during 1966-67. The work load at the Facility increased with respect to the processing of radioactive waste. Approximately 720 gallons of liquid radioactive waste were processed during the year, compared to approximately 440 gallons processed during 1966-67.

3. Reactor Radiation Protection Office. The principal services continue to be instruction of personnel, radiation surveys, sample analyses, and providing radiation protection services for sample irradiation, control-rod or fuel-element changes, and other reactor maintenance operations.
During the year, instrumentation for the environmental area monitors around the reactor site was improved by the calibration and installation of new radiation detection equipment.

4. Lincoln Laboratory Radiation Protection Services. Lincoln Laboratory visits by R.P.O. personnel continued during the year on essentially a weekly basis, supplemented as needed with additional visits for specific problems. Liaison is maintained with the Safety Office and First Aid Office.

The Accelerator Laboratory continues to be the principal area requiring R.P.O. services. No major new use of radiation sources occurred during the year. The ten-curie strontium-90 beta-ray irradiation unit was modified with a new shutter mechanism and all operations involving handling of the ten-curie source were performed by R.P.O. personnel.

Special projects undertaken during the year were:
1. The Laboratory for Nuclear Science's (L.N.S.) 400 MeV electron Linear Accelerator Project required considerable attention from various staff members during the fiscal year. Review of detailed construction plans by various members of the staff during the late summer and early fall resulted in recommendations for several minor and some major changes in the proposed facility. June Matthews, working jointly for R.P.O. and L.N.S., spent the summer and fall checking the adequacy of the design with respect to primary shielding; induced activity in shielding vault air, ground water, and machine parts; and radiation dose rates outside the vault from direct radiation, skyshine, and airborne constituents. Much time was spent in early 1968 by John W. Harvey and Francis X. Massé, working with L.N.S. personnel on shielding plans, interlock systems, research programs, and internal monitoring. Mr. Massé has been responsible for the designation of pre-operational monitoring equipment and siting, and is presently supervising the conduct of this program that began routine operation in early 1968, an estimated two years before operation of the machine. Concurrently, a pre-operational program for the establishment of groundwater contamination levels at various times of the year is in effect. Dr. Harvey and Mr. Massé sampled and evaluated the radioactivity content of representative soil samples throughout the site in the fall of 1967, before construction started. This has been well documented and will be used for future reference as necessary. The development of the permanent monitoring program for use during machine operation, both inside the facility and in peripheral areas, is now of prime concern. Mr. Massé is reviewing the monitoring programs of other high-energy machines in this country, making site visits as necessary, and is working with L.N.S.
on the design of the monitoring systems to be used at this machine. A full-time technician will begin working on this project for R.P.O. in July, 1968, his time to be divided between maintenance of the pre-operational monitoring programs and construction and/or assembling and testing of instrumentation for the monitoring systems now being designed.

2. The R.P.O. shadow-shield whole body counter, designed by Mr. Massé and Murray M. Bolton Jr. two years ago, has handled an increasing work load during the year, as the numbers of reactor people and persons working with significant quantities of unsealed gamma emitters have increased. Incidents of suspected inhalation of radioisotopes of iodine resulted in several attempts to quantitate $^{125}$I and $^{131}$I in radioisotope workers' thyroids with this device. However, it was determined that the efficiency of this unit for detecting the low-energy gammas from $^{125}$I was not adequate for detecting significant thyroid depictions of this isotope, and the chair, as originally designed, did not lend itself well to counting the thyroid. A thyroid probe modification, with a scintillation crystal that will detect all of the iodine isotopes, has been designed and constructed. Initial calibration data indicates that 1 per cent of a maximum permissible thyroid burden of $^{125}$I and $^{131}$I may be detected. It is planned to count routinely the thyroid of persons handling unsealed radioiodine in quantities greater than 5 mCi.

3. During 1967-68, Raymond Diffley Jr. provided technical assistance relative to radiation protection for the installation of a 250 KV X-ray unit by the Department of Humanities, and for the installation of a 1,000-watt CO$_2$ laser by the Department of Civil Engineering.

Other activities included:

1. Applied research. During the year, a procedure was developed by Dr. Harvey to analyze routinely the concentration of the rare gases present in the reactor stack effluent. The procedure basically consists of freezing out Xenon on a charcoal trap at dry ice-acetone temperature. The charcoal is then counted and analyzed to obtain the concentration of a particular Xenon isotope ($\text{Xe}^{135}$). From a knowledge of the fission yields of the other Xenon and Krypton isotopes the concentration of all the Krypton and Xenon isotopes can be determined. Measurement results showed no evidence of any appreciable halogen activity in the reactor effluent.

Mr. Bolton has continued his investigation into the use of activation analysis for the determination of beryllium. During 1967-68, radiochemical procedures were developed and successfully applied to urine specimens that were spiked with less than ten micrograms of beryllium.
Additional studies are planned using lung tissue containing less than one microgram of beryllium.

2. Teaching. During each term, a nine-hour training course on radiation protection was presented to graduate students of the Department of Nuclear Engineering. Informal lecturing, principally to new radiation workers, continues to occupy a significant fraction of the R.P.O. staff member time.

3. M.I.T. committee participation. Samuel Levin served as Secretary of the Radiation Protection Committee and was a member of the Reactor Safeguard Committee. Mr. Massé was Secretary of the Radiation Protection Committee's Advisory Committee on Medical Use of Radioisotopes.

4. Miscellaneous professional activities. During 1967-68, Mr. Massé was President of the New England Chapter of the Health Physics Society.

Mr. Diffley and Mr. Levin have continued to work with the Massachusetts Department of Public Health on laser-hazard evaluation and control. In February, 1968, Mr. Levin was appointed to the Department of Public Health's Laser-Hazard Advisory Committee.

ALBERT O. SEELER

PLACEMENT BUREAU

STUDENT PLACEMENT

As is the case every year, 1967-68 presented a new and varied series of problems to the Placement Bureau. No two years are alike for an office providing support to students in their quest for meaningful careers. The year just concluded was the year of dissent, cutbacks in Federal funding for research and development, and changes in the Selective Service regulations, all of which had an impact on the activities of this office.

With careful planning and good communications between this office, the Dean of Student Affairs office, the Faculty, and those students who disagreed with the right of organizations like the Dow Chemical Company and the Army to recruit openly, problems of the magnitude of those at the University of Wisconsin and others were averted. Although demonstrations protesting against both the Dow and Army visits were staged outside the Placement Bureau, they were orderly and peaceful, with no attempt to disrupt the activities of the office or to prevent others from free access.

Cutbacks in Federal spending for research and development which came in late fall and early winter had a noticeable effect on the recruit-
ing activities of many organizations. For the first time in several years, we observed a buyer's rather than a seller's market. Conversations with many recruiting representatives revealed that their efforts were being curtailed; they visited far fewer colleges and universities than in previous years. Although this development had its effect here, the demand for the M.I.T. product continued, but perhaps not as great as recently.

The major impact of the year came in February with the changes announced by the National Security Council regarding the discontinuation of student deferments for most fields of graduate study. In an effort to provide as quickly as possible reliable information to the student body, as to how the changes would affect them, an open panel meeting was called for the following week, presided over by the Director of Placement, with Dean Sanborn C. Brown of the Graduate School office and Colonel Paul Feeney of the Selective Service System participating. The meeting served to calm the fears of many students, providing forthright, meaningful information about the impact of the regulation changes on their careers. The effect was seen immediately, as students sought out a wider selection of employers than ever before, looking indeed to those with which they were likely to find occupational deferments, but also to those that offered interesting and valuable experience, even if military service should follow. Interest rose too in the various armed forces, with a greater number entering the military than in recent years. Although interest in attending graduate school remains high, the percentage of our students continuing on will undoubtedly be lower than recently.

ALUMNI PLACEMENT

It has been as busy a year as usual in Alumni Placement. Both engineering and manufacturing companies are searching hard for the young executives who are becoming more and more difficult to locate, partly as a result of the tendency in recent years to continue on to graduate school and partly, of course, because of the military situation.

On the last day of June in 1968, 677 men were registered with this office. Of these, 21 per cent had a Ph.D. or Engineer degree, and 35 per cent of the men who were interested in obtaining a new position were between the ages of 32 and 40. This is how the figures compare with figures on the same date ten years ago:

<table>
<thead>
<tr>
<th>June 28, 1968</th>
<th>Ten years ago</th>
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<tbody>
<tr>
<td>Men registered for job change</td>
<td>677</td>
</tr>
<tr>
<td>Men holding doctoral degrees</td>
<td>141 (21%)</td>
</tr>
<tr>
<td>Men between 32 and 40 years of age</td>
<td>35%</td>
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Last year M.I.T. granted 7 per cent more doctorates than it did ten years ago. The more rapid increase among those who want to change positions may be because many of them accept their first employment with organizations which have a strong military or aerospace orientation and after a few years are anxious to move into a field which is, perhaps, less exotic; and we note many men who come in to say they would like to transfer into research in the medical or medical equipment field. In addition, company mergers, and cutbacks in government spending for research and development are two more reasons why men are looking for new positions.

STUDENT EMPLOYMENT
The year showed a marked increase on the part of the M.I.T. student in part-time employment. This was particularly noticeable in the greater number of off-campus opportunities which were filled and in a particularly successful tutoring service encompassing the Greater Boston Area. Not only were there more challenging positions available, but the students have found these off-campus jobs lucrative.

The cutback in Federal funds for research and development tightened the job market significantly during the late spring. The summer outlook for those who did not take early action has consequently been a disappointing one.

THOMAS W. HARRINGTON JR.

OFFICE OF PUBLIC RELATIONS
This year the Office of Public Relations started new projects which should prove useful for the Institute as a whole in the future.

With support from key administrative officials, the office has initiated a library of 35mm color slides depicting all aspects of M.I.T. life. The library will be available to those who need slides for general or specialized presentations. Keeping the library fresh and up to date will require continuing attention.

The staff, again with help from other offices, is also studying how M.I.T. can obtain and use motion picture materials most effectively. John G. N. Rushbrook, who will shortly receive the Ph.D. degree in communications from Syracuse University, where he has been teaching at the Newhouse Communications Center, will join our staff in September and devote special attention to the film project, an area in which he has unique competence. Mr. Rushbrook replaces R. Eugene Bullock, who has left to enter industry.
The educational television series, *Science Reporter*, produced by M.I.T. and WGBH for more than a decade, was terminated this year and in its place M.I.T. and WGBH are exploring the use of available resources for special in-depth programs. An experimental step in this direction already has been taken with Professor Philip Morrison's program on wave motion.

In external communications, the public relations staff generated 218 releases on M.I.T. affairs, including 26 dealing with specific important achievements in research. Special support was provided for alumni conferences in Dallas and Philadelphia, the Wellesley-M.I.T. exchange program, dedications of the Center for Space Research and Eastgate apartments, the Instrumentation Laboratory's APOLLO guidance system, student systems engineering subjects, scientific conferences, and the Middleton linear accelerator. In addition, the public relations staff coordinated M.I.T.'s participation in the highly successful Tech Square Fair, which was an innovation in community relations.

In internal communications, *Tech Talk* circulation grew to more than 12,500 this year and the popularity of its classified ads has become such that the editor, Miss Joanne Miller, has had to set restrictions to insure that the medium is available only to members of the M.I.T. community. *The Institute Calendar*, now in its second year with a new format, has climbed to a circulation of 10,000 and has a new editor, Mrs. Betty Banks, replacing Miss Judith Werner, who resigned. *Reports on Research* also enjoyed continued popularity, judged by correspondence from readers who receive it on a limited distribution basis. Ellison W. Smith, who has edited *Reports on Research* for four years, will be leaving us soon and a qualified replacement is being sought.

The Office of Publications, directed by Mr. William T. Struble, continued to be judged outstanding among American universities and this year established an international reputation for imaginative institutional graphics.

For the second year in a row, the Institute's publications received the highest award in the competition conducted by the American College Public Relations Association.

In professional exhibitions, an ever-growing number of juries honored publications produced by graphic designers Mrs. Jacqueline S. Casey, Ralph M. Coburn and Dietmar R. Winkler. The American Institute of Graphic Arts chose 11 M.I.T. publications for display in its annual exhibition — an unusually high number from a single institution. Six of our publications appeared in *Graphis Annual*, the international journal of graphic art published in Switzerland. M.I.T. was represented by 11
VICE PRESIDENT, ACADEMIC ADMINISTRATION

publications in *Modern Publicity*, a London publication that makes an annual selection of the best in international advertising art; this year's edition contained 500 illustrations selected from 4,328 entries from 32 countries. *International Poster Annual 67-68*, published in Switzerland, reproduced six M.I.T. posters among "the 666 of the finest posters produced throughout the world"; entries were from 32 countries.

In a review of U.S. college publications, *CA Magazine*, the journal of communication art, noted, "the M.I.T. publications team produces a varied range of print design... that reflect(s) an authoritative image for the school." *CA*'s comments supported M.I.T.'s investment in its publications efforts: "College administrators, while keeping a careful eye on costs, realize that publications are the most effective and efficient way to reach specific audiences with total control of message and impression, and are recognizing the value of well-written, well-packaged publications."

M.I.T. publications were also selected for inclusion in *CA Annual*, in the Mead "Creativity on Paper" exhibition, in the Mead Annual Letterhead Exhibition, and in *Art Direction*. Mrs. Casey enjoyed a special honor when she was invited to display her work in a one-man show in *Directions 68*, sponsored by the Philadelphia College of Art.

Within the Institute, the demand for publications services continued to increase. During the year, the Office of Publications was involved in 285 publishing projects, with a total cost of more than $350,000. New accounting and business procedures have been instituted to help handle the increased volume more efficiently. A part of the reorganization was the appointment of Glenn T. Curtis, a graduate in printing arts of the Rochester Institute of Technology, to coordinate the purchasing of typesetting and printing services.

FRANCIS E. WYLIE
This section includes reports from the administrative units of the Institute that report to the President through the Vice President, Research Administration: the Division of Sponsored Research, the Libraries, the Summer Session, the Operations Research Center, the M.I.T. Press, the Francis Bitter National Magnet Laboratory, the Cambridge Electron Accelerator, and the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University.

In the Division of Sponsored Research we continue to be faced with the same two major problems that were discussed in the report for last year; first, the severe budget restrictions that have been placed on the principal government agencies from which we derive our major support and, second, the increased pressure for university cost sharing, both negotiated cost sharing and underrecovery of overhead due to overhead limitations in grants supported by the Government and foundations. The amount of cost sharing for this year was approximately 1.7 million dollars, which is a major drain from other university resources and thus becomes a major factor in meeting the total academic budget.

We expect further intensification of these problems in the coming fiscal year but at this time are unable to assess the impact fully, particularly the effect of the proposed six billion dollar cut in Federal spending. In any case the outlook is causing considerable gloom in the entire scientific and engineering community.

The total dollar volume of academic sponsored research increased by about 4.5 million dollars over fiscal 1967 to a total of more than 55 million dollars. However, these figures are misleading in that they do not truly reflect the problems facing the majority of the members of our faculty who are supervising sponsored research programs. We have more
than 900 active grants and contracts and most of them were either reduced or remained constant in dollar volume. The result is an actual reduction in research, since an annual increase of about seven per cent is required to meet escalation in costs for salaries, materials, and services.

The major significant increase in research funds was from the Department of Health, Education and Welfare. We expect approximately the same total dollar volume to hold in fiscal 1969 although there may be some increased support in areas such as transportation, pollution control, oceanography, weather modification, and urban affairs.

The university share of the total research and development budget in the United States is small and therefore only a very drastic reduction will have a significant effect on total Federal spending. The total Research and Development budget in the United States may be divided into four sections — industry, Federal government, colleges and universities, and other non-profit organizations. Of the total of about 24 billion dollars expended annually, industry spends about 16 billion, more than half of which is financed by the Federal government. The Federal government spends about four billion in its own laboratories. Only about 1.5 billion flows into the colleges and universities from Federal sources, which is augmented by about one billion more from university funds and foundation grants.

The most serious effect of the cutback in funding is the decreased support for graduate students. To maintain the standards of previous years requires not only increases to cover rising costs of salaries, wages, materials and services, but also increases for updating equipment, particularly expensive research tools and other costs connected with greater sophistication of research, for example, computer time and data processing. For adequate funding these should add up to an annual increase of about 15 per cent. We are, therefore, falling behind rapidly in maintaining graduate education standards if budgets are held constant for any period of time.

The end of the year marked a significant milestone in the history of the Division of Sponsored Research, the retirement of Dr. F. Leroy Foster, who has ably served the Division for almost 30 years and for the past 12 years has directed all of its complex activities with distinction. He has been replaced by Stuart H. Cowen, who will continue also to serve as Director of Fiscal Planning at the Institute. He will be assisted by three Associate Directors — George H. Dummer, Frank R. Stevens, and Richard N. Smillie.

Library problems also continue to intensify at all leading universities as the volume of scientific and engineering literature expands at an ex-
plosive rate. The only solution, other than providing more space and greatly increased budgets, seems to be in radical changes in library procedures and information transfer. Our hope is that Project INTREX will provide some relief, but in the short term we shall have to increase both capital and operating budgets.

Project INTREX (Information Transfer Experiments) is now in its third year of operations under the general direction of Professor Carl F. J. Overhage. The project has been established with the twofold objective of finding long-term solutions for the operational problems of large libraries and of developing competence in the emerging field of information transfer engineering. The research activities of the project are going forward in the M.I.T. Electronic Systems Laboratory under the direction of Professor J. Francis Reintjes. During the past year, effort has gone forward on two specific sets of experiments: (1) augmented-catalog experiments and (2) text-access experiments.

Under the sponsorship of the National Science Foundation, Project INTREX is developing a digitally encoded computer-stored "augmented" catalog of 10,000 documents in selected areas of materials science and engineering. Three groups in the Electronic Systems Laboratory are concurrently generating the data bank of bibliographic information, designing the necessary storage and retrieval programs, and developing an experimental console for interrogating the data bank. By fall of 1968 it is anticipated that the data bank, storage and retrieval programs, and augmented-catalog console will be available for experiments with a selected community of users at M.I.T.

The text-access experiments have been sponsored during the past year by the Council on Library Resources, Inc. The purpose of these experiments is to gather operational experience with a system which is designed to provide guaranteed rapid access to documents at locations both in and remote from the library. The full text of the documents, which have been cataloged for the augmented-catalog experiments, is being placed on microphotographic records. The records will be stored and retrieved using an electromechanical device under computer control. The selected record will be electronically scanned and the resultant electrical signal transmitted to remote terminals. The group has completed measurement of the transmission characteristics of the system and is currently preparing two terminals for use: a storage-tube device and a 35-millimeter film station employing a high resolution cathode-ray tube and a camera processor unit. It is anticipated that the entire experimental text-access system will be available by fall of 1968 for evaluation by our community of users.
The Engineering Library, which will be the operational environment for carrying on the INTREX experiments, is currently being rebuilt. The new facility, which is expected to be in operation in the spring of 1969, will combine the functions of a conventional library with those of a laboratory for new methods of information transfer.

CARL F. FLOE

FRANCIS BITTER NATIONAL MAGNET LABORATORY

In November, the Laboratory was renamed in honor of Professor Francis Bitter. Professor Bitter, a member of the M.I.T. Faculty for 33 years until his death in July, was a cofounder of the Laboratory. It was his development of the water-cooled magnet at M.I.T. in the thirties which marked the beginning of high-field research in this country. The modern water-cooled magnets used at the Laboratory are based on his design and Bitter magnets are in use throughout the world. Professor Bitter made many important contributions to the understanding of atomic physics, magnetism, and plasma physics.

Plans for augmenting the capability of the Laboratory have been formulated and are incorporated in a five-year plan which is being prepared at the request of the U.S. Air Force. The plan is centered around the revolutionary concept of the hybrid magnet, which is a combination of a large-volume superconducting magnet surrounding a water-cooled solenoid. This is a preferable alternative to the all water-cooled design which has been under consideration for several years. The new scheme will permit the achievement of a large hybrid magnet capable of attaining a 300-kilogauss steady field for the first time. In addition the plans call for a number of hybrid magnets in the 200 to 300 kilogauss range which will upgrade the high field capability of the Laboratory significantly. To take full advantage of these advances, the research staff will be increased and at the same time many additional visitors will be accommodated. A prototype hybrid magnet designed to provide 225 kilogauss with five megawatts in the water-cooled section is now under construction and will be ready for testing about the end of 1968.

Magneto-optical research at the Laboratory has undergone a considerable change mainly due to the more extensive use of modern optical tools. Several non-linear magneto-optical studies at high magnetic fields have now been completed. These include multiphoton photoconductivity and non-parabolic magneto-optical non-linearities. Experimental and theoretical work on time-dependent tunneling in a magnetic field has
established the mechanism of multiphoton processes in semiconductors. Magnetoplasma-photon studies have been carried out by reflection experiments using a Fourier transform far infrared spectrometer. Excellent correlation between experiment and theory was obtained by analyzing the data using the Kramers-Kronig relation. Submillimeter cyclotron resonance in high magnetic fields by means of a CW cyanide laser has permitted the observation of quantum effects in germanium and indium antimonide. These measurements allow quantitative interpretation of cyclotron resonance in p-type indium antimonide for the first time. The modulation techniques involving electroreflection in HgTe and piezo-transmission in germanium have provided significant additional information on the complexities of the band structure of these materials. In a cooperative program with the University of Illinois, the effective mass of the polaron in five ionic compounds has been measured for the first time. These masses were obtained from cyclotron resonance experiments at two millimeters wavelength and fields up to 100 kilogauss.

Staff members of the Transport and Resonance Group, the Theoretical Group, and the Low Temperature Group, are jointly studying several aspects of magnetism and the closely related phenomenon of superconductivity. Basic problems in the magnetism of metals are being studied in systems which are strongly paramagnetic or weakly ferromagnetic in order to test and interrelate the recent theories on the effects of critical spin fluctuations, the nature of the spin compensated state, and the possibility of inducing ferromagnetism with applied magnetic fields. In the strongly paramagnetic systems it has been shown here that extreme care must be taken in order to avoid overestimating the susceptibility and exchange enhancement. The systems displaying a spin compensated state are being studied using magnetization, magnetoresistance, electron spin resonance, and Mössbauer techniques and are also being considered theoretically. The high magnetic fields produced at the Laboratory are necessary in order to compete effectively with the magnetic fields found in these weakly magnetic systems. The metals and alloys being studied include pure Pd, PdAg, PdRh, PdFe, CoFe, ZrZn₂, and alloys of NiRh, especially in the critical concentration region where ferromagnetism occurs and where the magnetic susceptibility has been reported to be very high. Concurrent theoretical studies of spin polarization around magnetic impurities in a magnetic metal have shown that the range and amplitude of the disturbance is very sensitive to the band structure of the host metal.

Measurements of the high field superconducting properties of V₃Ga and V₃Si have provided a measure of the importance of Pauli spin
paramagnetism on the upper critical field of these materials. Studies of niobium nitride have confirmed a theoretical model for the peak effect in superconductors. High field magnetization measurements on the new superconductor, NbGeAl, show it to be an extremely promising material. The material is being synthesized by a group at the University of California at La Jolla and the Bell Telephone Laboratories. Ribbons of superconducting V₃Ga made in the National Research Institute for Metals, Tokyo, have been studied in fields up to 211 kilogauss. The best samples have much higher critical currents than Nb₃Sn in the field range from 120 to 211 kilogauss. A new quantum mechanical representation to describe the motion of an electron in a crystalline solid has been developed. This elegant and simple scheme, known as the kq-representation, is particularly suitable for calculating the effect of electric and magnetic fields and will simplify the solution of many outstanding theoretical problems in solid-state physics.

A program to develop a magnet system for the guidance of catheters through the blood vessels of the head and neck is under way in cooperation with the Neurosurgery Service at the Massachusetts General Hospital. The possible use of superconducting magnets for a more advanced system is being studied. Additional practical applications of high magnetic field techniques to problems in science, technology, and medicine are being explored.

The 1967 International Congress on Magnetism combined with the Annual Conference on Magnetism and Magnetic Materials met in Boston and Cambridge in September. Several Laboratory staff members were active on Congress committees. About 400 members of the Congress visited the Laboratory on scheduled tours and on special visits with individual staff members throughout the week.

Dr. Arthur J. Freeman, Associate Director of the Laboratory and Leader of the Theoretical Group, relinquished these positions in August to become Chairman of the Department of Physics at Northwestern University. Elmer W. L. Davis, formerly head of the Administrative Group, was promoted to Assistant Director for Administration in July. Dr. Brian B. Schwartz, Associate Leader of the Theoretical Group, was promoted to Leader of that group in August.
of this report, research groups composed of staff members and graduate students from M.I.T., Harvard, and other institutions worked on 18 experiments including, among others, the elastic scattering of photons, the production of mesons with polarized photons, the scattering of electrons from hydrogen and deuterium, and a test of time invariance in the electromagnetic interaction.

In parallel, an exciting development program has been carried out, the ultimate goal of which is to produce head-on collisions between 3 BeV electron and positron beams rotating in opposite directions in the accelerator ring. This will permit studies of the basic electromagnetic interaction up to an effective energy of 6 BeV, a value higher than has been available up to now.

KARL STRAUCH

DIVISION OF SPONSORED RESEARCH

The most significant factors affecting the operations and organization of the Division during fiscal 1968 were the changing pattern of support in a broad range of programs, including research, institutional development, student financial assistance and training, facilities, urban affairs and community service; administrative problems similar to those of the previous year and resulting from the diversity of programs and sponsors as well as from dealing with new or expanded agencies not yet geared administratively to deal with the expanded role thrust upon them; and the problem of predicting and anticipating for fiscal 1969 the impact of budget cuts enacted by Congress in the last weeks of fiscal 1968 but not yet translated into actual reductions in programs from which M.I.T. receives support.

SPONSORED RESEARCH

In fiscal 1968 the volume of sponsored research performed in academic departments and interdepartmental laboratories and administered by the Division increased by approximately 9 per cent over the fiscal 1967 figure of $50,597,000. The increase was shared in varying degrees by all of the schools. The largest gain was in the School of Science, with an increase of two million dollars or 16 per cent; the School of Engineering increased about $400,000 or 3 per cent. In addition, the interdisciplinary laboratories as a group increased by $1,900,000.

In the Federal sector, comprising 90 per cent of fiscal 1968 sponsored research volume, support by the Department of Defense (DOD), roughly
one-third of total volume, increased slightly, while support from the National Aeronautics and Space Administration decreased slightly but was more than offset by a significant increase from the Department of Health, Education and Welfare and by moderate increases from the National Science Foundation (NSF) and the Atomic Energy Commission.

Foundations and other non-profit organizations, as in the preceding fiscal year, supported approximately 5 per cent of the Institute's sponsored research, with decreased support from a number of such sponsors balanced by an increase from the Ford Foundation. In addition, a three-million-dollar Ford Foundation grant for urban studies, including three endowed professorships, was received in mid-year but will not have any substantial impact on research volume until fiscal 1969. Industrial support increased by about 20 per cent and again represented 5 per cent of total sponsored research.

**IMPACT OF FEDERAL BUDGET CUTBACKS**

The large percentage of university research support derived from the Federal government is a cause for increasing concern to M.I.T. as it is to the entire educational community in view of the present pressures on the Federal budget and the recent legislation requiring a six-billion-dollar cut in fiscal 1969 expenditures. Until now, faculty members have been reasonably successful in obtaining alternative sources of research support for their programs despite cutbacks in individual sponsoring agencies. Barring an early settlement to the Vietnam conflict, however, it seems likely that reductions in Federal support will be deeper and more widespread. With non-government sponsored support at M.I.T. comprising only 10 per cent of total volume, a general reduction in Federal support will not easily be offset.

In addition, any general retrenchment in Federal research funding will be aggravated in some agencies by the tendency of Congress to prohibit reductions in programs intended to achieve geographic distribution of research funds or create new centers of excellence. Such restrictions placed on the DOD's THEMIS program and on NSF's Science Development Program in the past have forced proportionately deeper cuts in programs in which the larger, more established institutions are involved.

A further consequence of the current budget uncertainty is that it is impossible to make timely personnel and other commitments for research programs during the next academic year without taking a serious financial risk. The uncertainty has been compounded by the temporary freezing of funds by several agencies this spring, most notably by the Department of Health, Education and Welfare, and the situation will not
DIVISION OF SPONSORED RESEARCH

become clear until the recent six-billion-dollar budget reduction has been allocated to each specific agency and program. It is even conceivable that this might remain unclear until the last half of the fiscal year.

One of the most useful means of avoiding such uncertainties has been to negotiate lead-time funding for the major laboratories whenever possible, but in the present climate this advance funding is under pressure. Project MAC has recently been reduced from three to two years advance funding and the Center for Materials Science and Engineering from four to three during a transition to step funding, the net effect of which will be a reduction to two years. The elimination of longevity funding is an attractive method of budget cutting from an agency point of view and more can be expected, thus aggravating the problems of making long-term commitments to high caliber research personnel and protecting the Institute against the risk of unexpected reduction or termination of research support.

Even if over-all research support simply leveled off, it would be difficult to maintain the present level of research inasmuch as the steady increase in competitive salary levels and in the cost of equipment and services would have the effect of reducing the research performed. Despite such a leveling-off of funding under its Joint Services contract, now roughly one-third of its volume, the Research Laboratory of Electronics has maintained and in some areas expanded its research program by obtaining increased or new support from other agencies. On the other hand the Francis Bitter National Magnet Laboratory, funded almost entirely by a single Air Force Office of Scientific Research (OSR) contract, also leveled off in 1968 and a reduction of 7 per cent is forecast for fiscal 1969. The net effect, however, will be closer to a 15 per cent reduction since a 5 per cent to 7 per cent increase would be required to maintain a stable research program.

FACILITIES PROGRAM

Federal support for the construction of academic and research facilities during fiscal 1968 remained at about the same level as the previous year. The Center for Space Research, supported in part by a three-million-dollar grant from the National Aeronautics and Space Administration (NASA), and the Center for Advanced Engineering Study, funded one-third by a $960,000 grant from the U.S. Office of Education, were completed and occupied during the year.

The Camille Dreyfus Building for graduate research in chemistry, funded in part by an NSF grant of $2,900,000, is under construction with completion expected in the summer of 1969. Two projects begun
in the fall of 1967 are now well under way — the renovation of the Engineering Library, funded in part by the Office of Education, and the building which will house the 400-MeV linear accelerator in Middleton, Massachusetts, toward the total cost of which the Atomic Energy Commission (AEC) has provided $4,600,000 and the Institute approximately one million dollars.

The largest project now under way is at this time in the planning and proposal stage — the Electrical Engineering and Communications Research Facility — and during fiscal 1968 the Division participated in the preparation of four proposals to Federal agencies requesting total support of more than $4,500,000 toward a total cost estimated at $12,200,000.

EDUCATION AND TRAINING PROGRAMS

Federally sponsored fellowships and traineeships showed a substantial increase in fiscal 1968 over the previous year due to the expansion of National Defense Education Act fellowships. As a result, total Federal support for graduate and postdoctoral students reached $3.5 million, a growth of roughly 13 per cent over 1967.

The National Science Foundation remained the largest single sponsor of fellowships, providing more than $1.9 million in support of 380 students. National Institutes of Health supported 120 predoctoral and postdoctoral fellowships, at the level of $565,000. Both NSF and NIH support were at roughly the same levels as in 1967.

Other Federal programs showed more fluctuation. The Office of Education's National Defense Education Act (NDEA) Title IV fellowship program, with 53 additional awards to M.I.T. students, almost doubled in size to a fiscal year level of $640,000. NASA's traineeship program entered the first year of its phase-out, with 39 men supported this year, six fewer than in 1967. Special fellowships from the AEC increased from 31 to 45, and a new program initiated by the Department of Housing and Urban Development (HUD) supported three students in the school of Architecture and Planning.

It might be noted that these new HUD fellowships are one of the few Federal programs to pay a student's full tuition at those institutions where tuition exceeds the usual $2,500 "Cost of Education Allowance," as it will at M.I.T. by nearly $400 in the next academic year.

Since there will be no new awards under the NASA Training Grant program next year, and there is the likelihood of budget cuts for the National Science Foundation and other agencies, a reduction in Federal fellowship support is expected next year.
The Division continues to participate in the administration of four programs for development of foreign universities, three of them in India and the fourth in Berlin, Germany. At the Birla Institute of Technology and Science in Pilani, India, the Ford Foundation program of faculty exchange, equipment, library, and curriculum development program achieved a high level of activity after moving from the planning to the operating stage during the previous year. For fiscal 1968, expenditures for the four international education programs were at roughly the same $900,000 level as in 1967.

ADMINISTRATION

Fiscal 1968 was another year of cross currents in administration. Some improvements were offset by the increasing number and complexity of government programs and regulations. The NIH pilot study, previously limited to research grants, was extended to cover training grants as well. By delegating to certain grantee institutions, of which M.I.T. is one, the authority to approve certain restricted expenditures and budget revisions, the pilot study has simplified administration of NIH grants. In addition, the Public Health Service, of which NIH is a major part, also put into effect a much simplified grant financial report which will reduce preparation time by a factor of approximately five. The new report reflects suggestions by a small group of universities including M.I.T.

Cost sharing and underrecovery of overhead continued to be an administrative and financial burden and amounted to approximately $1.7 million for fiscal 1968.

Responding to continued demands for information, both for Federal agencies and for M.I.T.'s internal administration, the Division has expanded its computer usage for data processing and information retrieval. Basic accounting data for on-campus research projects is combined periodically into a data base available for computerized inquiry. The Division uses the computer at M.I.T.'s Office of Institutional Studies with a combination of programming languages which provide fast, economical production of special-purpose reports.

The Division also employs this data processing system for planning purposes and by projecting the commitment of M.I.T.'s personnel, space and other resources to the research effort, it may be useful to other administrative functions as well.

In addition, a file of information on research proposals is being maintained on the M.I.T. Compatible Time-Sharing System, which represents the first time that the Division has used data from sources other than the accounting computer system. Through the use of the Division's
teletype facilities, this file is readily available for inquiry and updating and will provide a new capability for analysis of research commitments and proposal activity.

F. LEROY FOSTER

JOINT CENTER FOR URBAN STUDIES

The growing involvement of the two universities, M.I.T. and Harvard, in the study of urban affairs has been marked in the present academic year by an award of three million dollars to each university by the Ford Foundation. This has made possible the establishment of five chairs in Urban Studies at Harvard. The grant to M.I.T. will allow for the establishment of an Urban Systems Laboratory, headed by Professor Charles L. Miller, a member of the Joint Center Faculty Committee, and head of the Department of Civil Engineering. M.I.T. will also establish three chairs and an Urban Fellows program which will encourage postdoctoral students and younger members of the staff to work with innovating urban agencies.

The present state of the country demands focus on urban problems in every aspect; not only on the civil disorders and the crises of the ghettos, but also on the fields of public transportation, medical services, the politics of cities, and economic and social problems. The involvement of the Joint Center in these matters of urgent concern has led to an expanding program with the cooperation of an increasing number of scholars from the academic world. The expansion of the activities of the Joint Center has involved an acceleration in the annual rate of spending of the Ford Foundation grant. It was originally planned to continue at the level of $200,000 a year, but in the year 1967-68 this was increased to approximately $300,000 by using up the remaining funds of the previous grant from the Ford Foundation. Other programs undertaken by the Joint Center, supported by grants and contracts from Federal sources and private foundations, increased the total expenditures for the year to more than $500,000.

One of the largest contracts undertaken by the Joint Center was to assist the Corporacion Venezolano de Guayana in preparing a development strategy for the Guayana region and in particular to help in the preparation of plans for the new city of Santo Tome de Guayana in Venezuela. This program is almost complete, and during the past year the Joint Center has been involved only in the final stages of preparing publications based on the study. About $60,000 of the contract funds
remain unspent, and it has been agreed at the request of the Corporacion Venezolana de Guayana to use these funds to finance students from Venezuela who wish to study at M.I.T. or Harvard.

**BASIC RESEARCH**

More than 50 specific studies have been included in the research activities during this academic year, and as in previous years the studies in urban social processes predominate. These cover matters of civil rights, disorders and riots, politics, and racial and welfare problems. The historical aspects have been explored in a study of American disturbances, riots, and insurrections such as the draft riot of 1863 and the Pittsburgh railroad riot of 1877; in a study of the Irish immigrants in nineteenth-century London; and in another study of the problems of education of immigrants in Massachusetts in the early twentieth century.

Much attention has been given by individual members of the Joint Center to the more important social issues of today, such as the problems of welfare, school desegregation, suburban delinquency, racial patterns in suburban areas of Boston, and the civil rights struggle.

In the past year the Joint Center has undertaken to evolve a preliminary design of a Health Information System for Boston. This program has involved the faculty of several departments at M.I.T. and professional staff of the Harvard School of Public Health. An exploration has been made of the methodology and strategy of initiating such a system. It has required investigation of the willingness of public and private agencies to participate and of safeguards to individual privacy. Study groups are examining computer capabilities, methods of assuring data validity, and estimates of the cost-benefits of the system.

The Metropolitan Boston Studies program is providing a liaison service to public agencies and other organizations in the Boston area. Its activities have included the drafting of redistricting proposals for the Task Force on Racial Imbalance of the Massachusetts Commission of Education, to alleviate racial imbalance in the Boston public schools. There has also been a survey of what measures might be taken to foster and strengthen the arts in Boston and of the sources of financial support of the arts.

Studies have been made by members of the Joint Center on automobile safety legislation, both on state and national levels. The economic and social aspects of urban transportation have been reviewed, particularly in relation to lower income groups.

Other fields covered by Joint Center research include some individual studies on urban design, rehabilitation, and urban planning.
VICE PRESIDENT, RESEARCH ADMINISTRATION

New programs for the coming academic year are now being established. These will include a study of air pollution, an annual survey of the Boston metropolitan area population, a study of the relationship of the university to the urban community, and a program in cooperation with the Behavioral Sciences Consultation Unit at Harvard's School of Public Health.

PUBLICATIONS

The Joint Center has published the proceedings and recommendations of a conference held in Washington in June, 1967, at which were discussed the inadequacies of social statistics for Negroes, Puerto Ricans, and Mexicans in the United States. This publication is titled *Social Statistics and the City*.

Two other books have been added to the Joint Center's list of publications during the past year:


Leon H. Mayhew, *Law and Equal Opportunity: A Study of the Massachusetts Commission Against Discrimination*. A case study which analyzes the forces that shape, facilitate, and obstruct the legal implementation of social ideals.

Two books by members of the Joint Center have been published by other organizations. The University of Michigan published Lisa R. Peattie's *The View from the Barrio*. This is an anthropologist's description of the life processes and environment in an urban neighborhood of a rapidly growing planned city in the interior of Venezuela. James Q. Wilson was the editor of *City Politics and Public Policy*, published by John Wiley & Sons, Inc. The book gives papers written by several scholars, among them members of the Joint Center, and deals with how things are done in the cities, especially with respect to public housing, urban renewal, race relations and land usage.

The Joint Center has continued its practice of holding weekly meetings attended by members and guests invited from the two universities. Among the speakers at these meetings were John Kenneth Galbraith, Edward J. Logue, Hale Champion, and Mayor John F. Collins. Professor Charles V. Hamilton of Roosevelt University spoke of Negro militancy, and Dr. Harvey G. Cox spoke on the urbanization and future of religion.

Several members of the Joint Center have talked at these weekly meetings on subjects relating to their research. Richard Bolan together with Justin Gray, Assistant to the City Manager of Cambridge, discussed the
plans for the Cambridge Model Cities grant. Jacob Rosenthal spoke on the Report of the National Advisory Committee on Civil Disorders.

DANIEL P. MOYNIHAN
LLOYD RODWIN

LIBRARIES

The outstanding event of the past year was the acquisition of our millionth volume, which was commemorated by a special ceremony at the Alumni Day luncheon. I. Austin Kelly III '26 donated to the libraries a mint condition copy of the rare 1855 first edition of *Leaves of Grass* by Walt Whitman. Another rare and precious gift was received this year. Arthur E. Vershbow '43 donated a copy of Galileo Galilei's *Dialogo . . . dei . . . Sistemi del Mondo*, published in Florence by Landini in 1632. The copy is complete with frontispiece, with the correction found only in the earliest printing and in a period binding, the whole in superb condition. Though our rare book collection is small and lacks suitable housing, it has a few fine specimens of the great books of the past. These two remarkable additions are received with gratitude. Also much appreciated are 1,670 other gifts from many good friends of the Institute libraries.

It was particularly appropriate that the symbolic millionth volume should be in the humanities to indicate the new position of strength in the collections assumed in the last few years by fields other than science and engineering. History, literature, fine arts, and the social sciences now account for well over one-half of our annual purchases, reflecting the new emphasis in the curriculum and the fact that these disciplines tend to be greater producers and consumers of verbal material.

GROWTH

The Dewey Library of Management and Social Science has had a most spectacular growth; in fact its acquisitions of 31,662 volumes this year (versus 27,834 in 1966-67) are 40 per cent of the total for all libraries. This comes not only from the nature of the fields covered but also from the enthusiastic support of the faculty and the availability of extra book funds from a Ford Foundation grant, plus supplementary financial support from the deans of the two schools involved when the regular funds were exhausted early in the spring.

The apportionment of resources between the School libraries and the changes in emphasis may be of interest. It should be noted that Dewey, despite budget increases, has fallen in per capita expenditures.
Table I  Five Year Comparison of Per Capita Expenditures by Library

<table>
<thead>
<tr>
<th>Library</th>
<th>1962-63 Students</th>
<th>1962-63 Budget</th>
<th>1967-68 Students</th>
<th>1967-68 Budget</th>
<th>Per Capita Increases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>224</td>
<td>$25,376</td>
<td>317</td>
<td>$125,145</td>
<td>249%</td>
</tr>
<tr>
<td>Humanities</td>
<td>179</td>
<td>60,995</td>
<td>344</td>
<td>181,259</td>
<td>54.2%</td>
</tr>
<tr>
<td>Dewey</td>
<td>259</td>
<td>74,074</td>
<td>1,044</td>
<td>201,995</td>
<td>-2%</td>
</tr>
<tr>
<td>Science</td>
<td>2,908</td>
<td>108,704</td>
<td>3,085</td>
<td>216,032</td>
<td>89%</td>
</tr>
<tr>
<td>Engineering</td>
<td>2,488</td>
<td>83,356</td>
<td>3,035</td>
<td>333,911</td>
<td>223.5%</td>
</tr>
</tbody>
</table>

* Does not include $6,000 in special appropriations for Humanities books; $1,000 for political science journals; $1,000 for political science books; $5,000 for Dewey Library serials and journals; $2,500 for Dewey Library books; and $110,000 for microfilming and operations for Engineering Library.

When you buy books, you have to find a place to put them; and when you buy them at a higher rate than anticipated, space runs out that much sooner; and that is what has happened at the Dewey Library, built only three years ago. Some parts of the collection are already overflowing but plans have been made to add more shelving on the first and second floors and substantial storage shelving in the basement. This should accommodate the library for about three more years at the present rate of growth. Table II shows volumes added, volumes in the library, and volumes loaned for each of the Institute libraries in the last two years.

The Dewey Library has been cited as an extreme example of what is going on all over the Institute. Seating capacity is adequate since the addition of 495 seats in the new Student Center Library two years ago, but space for shelving books has run out or is running out in all our libraries. A number of plans are under discussion for new library facilities, the most ambitious of which would combine the libraries of the three schools, Architecture and City Planning, Humanities and Social Science, and Management, in a new building. No decision has been made but we hope one will be forthcoming in the near future. Not until a long-range policy for accommodating the libraries has been adopted can sensible interim decisions for the next five years be made.

One aspect of the future of library service for the Institute that needs to be decided is how the proliferation of reading rooms of various sizes shall be controlled and under what circumstances they should be part of the official library system. Up to the present no stated policy exists, only a general assumption that large reading rooms should be part of the official system while small ones need not be.

This year two departmental libraries of substantial size are being planned: chemistry (4,500 square feet) and physics (5,200 square feet).
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</thead>
<tbody>
<tr>
<td>Archives</td>
<td>1,053</td>
<td>753</td>
<td>17,877</td>
<td>18,627</td>
<td>70,206</td>
<td>77,694</td>
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<tr>
<td>Dewey</td>
<td>28,267</td>
<td>31,662</td>
<td>217,202</td>
<td>248,592</td>
<td>39,051</td>
<td>49,795</td>
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<tr>
<td>Engineering</td>
<td>14,344</td>
<td>10,292</td>
<td>137,052</td>
<td>146,623</td>
<td>3,645</td>
<td>2,250</td>
</tr>
<tr>
<td>Aeronautics and Astronautics</td>
<td>5,020</td>
<td>4,181</td>
<td>64,823</td>
<td>68,923</td>
<td>1,345</td>
<td>1,558</td>
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<tr>
<td>Materials</td>
<td>338</td>
<td>210</td>
<td>506</td>
<td>699</td>
<td>1,645</td>
<td>2,250</td>
</tr>
<tr>
<td>Space</td>
<td>1,272</td>
<td>1,186</td>
<td>5,112</td>
<td>6,297</td>
<td>1,345</td>
<td>1,558</td>
</tr>
<tr>
<td>Humanities</td>
<td>13,754</td>
<td>10,843</td>
<td>167,926</td>
<td>176,275</td>
<td>33,407</td>
<td>36,373</td>
</tr>
<tr>
<td>Music</td>
<td>1,119</td>
<td>639</td>
<td>12,205</td>
<td>12,841</td>
<td>4,835</td>
<td>3,808</td>
</tr>
<tr>
<td>Reserve Book Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,266</td>
<td>10,681</td>
</tr>
<tr>
<td>Rotch</td>
<td>4,983</td>
<td>5,663</td>
<td>59,925</td>
<td>65,140</td>
<td>18,503</td>
<td>19,861</td>
</tr>
<tr>
<td>Science</td>
<td>11,804</td>
<td>8,241</td>
<td>271,136</td>
<td>279,233</td>
<td>47,451</td>
<td>55,200</td>
</tr>
<tr>
<td>Lindgren</td>
<td>2,017</td>
<td>1,806</td>
<td>16,362</td>
<td>18,161</td>
<td>4,390</td>
<td>4,588</td>
</tr>
<tr>
<td>Student Center</td>
<td>7,044</td>
<td>3,652</td>
<td>13,515</td>
<td>17,167</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>91,015</strong></td>
<td><strong>79,128</strong></td>
<td><strong>983,641</strong></td>
<td><strong>1,058,578</strong></td>
<td><strong>241,313</strong></td>
<td><strong>271,863</strong></td>
</tr>
</tbody>
</table>
They may provide useful precedents. Both will be operated as part of the library system. Both will be composed almost exclusively of duplicates of material in the Science Library. Both will be open reasonably long hours, non-circulating, and with keys issued to senior faculty members and others who need to use the collections when they are closed. The chemistry reading room, according to present plans, will be unusual in that back sets of the approximately 45 journals will be provided entirely on film. A substantial number of film readers and reader-printers will be provided and only books and current issues of journals will be on paper. As far as is known, no other university has attempted to satisfy the needs of faculty, students, and research staff in chemistry with a film collection of journals, though a few in industrial libraries have. Careful estimates have shown that start-up and operating costs will be nearly identical for this type of facility and a conventional one. We hope that the availability of the same material on paper in the Science Library will make possible comparative studies of the preferences of the users as they work with the collections.

The new reading rooms for chemistry and physics should be opened next year and at that time a diminution in the use of the Science Library by faculty and graduate students can be expected. This will make the Science Library a quieter place to work.

No relief from the growth of the book collections in Science can be anticipated, nor in the other libraries. The relative growth rates of the different libraries may be of interest. Science and Engineering start with a large base and Engineering has been discarding earlier works, some of which have been added to Humanities because of their historical value.

<table>
<thead>
<tr>
<th>Table III</th>
<th>Three Years of Net Growth, by Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library</td>
<td>1965-66</td>
</tr>
<tr>
<td>Dewey</td>
<td>11.4%</td>
</tr>
<tr>
<td>Engineering</td>
<td>9.9%</td>
</tr>
<tr>
<td>Humanities</td>
<td>6.2%</td>
</tr>
<tr>
<td>Rotch</td>
<td>8.9%</td>
</tr>
<tr>
<td>Science</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

When the price of individual books is going up nearly 10 per cent a year and journal subscriptions 25 per cent a year, when the number of published pages is going up 10 per cent a year, and when the number of fields in which advanced research is being done at the Institute is steadily increasing, the Libraries are faced with a set of inflationary factors that forces them to run in order to stand still. In order to main-
tain the same relative quality of collections, the Libraries have to have budget increases averaging more than 10 per cent a year and additional space of about 10 per cent a year. If costs are going up faster than appropriations and the latter are always a year behind, budget deficits have to be expected. Trying to gain headway in such a situation is distressingly reminiscent of the myth of Sisyphus. There is, however, one ray of light. That is the hope that by better selection we can reduce the rate of growth while still improving quality.

This year a new group formed by the Provost and composed of deans and top administrative officers met with the Executive Board of the Faculty Advisory Committee on the Libraries. They recommended that since better selection seemed to be the only way to gain against the inflationary tide, the Director should start work immediately on a selection policy to guide faculty members and librarians in the choice of new titles. Such a policy would have a second beneficial effect in that, by specifying the level of collecting in each subject for each library, it could reduce, even eliminate, unnecessary duplication. Duplication may be justified by demand. The case is particularly clear with reserve books and also with a number of high-demand journals. Normally, however, one copy can be expected to satisfy the probable demand and further copies are an extravagance in money and space.

A draft selection policy has been prepared and distributed to library department heads with the goal of completing discussions with appropriate faculty committees by June, 1969. We would like to introduce a policy along with a mechanism for enforcing it at the beginning of the following academic year.

**MANAGEMENT STUDIES**

Four management studies of different aspects of the libraries' operations have been made during the year. The most extensive of these started as a subject project, turned into a Bachelor's thesis, and will be published in the fall as a report from the Center for International Studies. Into the report will also be incorporated a second cost-benefit study based on a questionnaire. Two other studies were done by a firm of outside consultants.

The first two studies started at the end of last year and were carried out by two students, Robert Shishko and Jeffrey A. Raffel; the former is an undergraduate and the latter a graduate student, both working under the direction of Professor Fred C. Iklé of the Department of Political Science. These studies are really a whole series of investigations, some addressed to the particular problems of the Dewey Library and
others bearing on the entire system. The two men worked closely together throughout the summer, interviewing librarians, making detailed cost and time studies, and applying systematic analysis to our operations. They came out with a program budget which for the first time brings to light the real total annual cost of operating the libraries, taking into account the amortization of land and buildings and giving breakdowns for acquisitions, cataloging, reserve books, book storage, readers' spaces, reference services, to mention only the principal ones. The program budget for the year worked out at $2,280,000 compared to library appropriations of $1,447,256.

On the basis of these studies it will be possible in the future to make more rational decisions on the allocation of funds or on alterations and new construction. One point of particular interest in Shishko's thesis, "An Application of Systematic Analysis to the M.I.T. Libraries," is the comparative costs of different types of book storage. The most generous type of open-faced shelving in reading rooms worked out at 28 cents per volume per year. The cheapest kind of compact storage at a remote location with low maintenance and building costs was 18 cents a volume. This apparently substantial difference amounts to only one per cent of the annual program budget; and it vanishes entirely if one takes into account the cost of setting up a retrieval system for remotely stored books, not to mention the delay in getting the books and the loss of browsability, to which cost figures could not be attached. Shishko's conclusion was: "Compact storage facilities should be placed within fast walking distance of the circulation desks to allow regular library personnel to retrieve books, thus eliminating the need for expensive motorized systems." Some of his other conclusions are: on reserve books, "The M.I.T. Libraries presently spend about three-quarters of their annual resources (estimate $2,280,000) to provide a general and research collection, and the remaining one-quarter to provide required reading and course-related study facilities"; on microfilm, "Marginal journals should be ordered on microfilm at the year's end, if available commercially"; on computers, "Computerized catalogs may be even better than we think, since they would allow: a) decentralized catalogs on campus which could be combined with fast messenger services, b) cooperative acquisition agreements with other nearby university libraries, and c) common access to other collections that were 'tied in' to the system."

Raffel's work was completed late in the year with a detailed analysis of a new type of benefit evaluation questionnaire sent in May to a random selection of representatives of faculty, graduate students, and
undergraduates. The reply ratio was only 40 per cent, which is partly accounted for by the time of year it was sent. Nevertheless, a number of attitudes came through clearly. Before turning to the results, a word about the unusual questionnaire may be in order. Raffel gave the respondents three possible budgets and asked on what items they would save and on what they would spend money. They were to reallocate money between services a) at the present budget level, b) if they had $100,000 more to spend and, c) with $200,000 more. It should be noted in passing that this was a sample of all potential users, not only of actual users.

Following are some of Raffel's results:

1. There is a general orientation toward increasing the library's role as a distributor of materials for use outside of the library. A majority of students and faculty would alter the present library in order to save money so that lower Xerox prices could be adopted.

2. There is a 'research orientation' and related to this orientation is strong support for marginal increases in acquisitions at the expense of other systems. Few desire a radical increase in acquisitions (such as 20 per cent) at the present budget level and virtually no one wants to decrease acquisitions to adopt any other system. Given more funds, however, a large increase in acquisitions is highly popular.

3. Centralizing the reserve book libraries appears to be very popular especially among those who presumably would be most affected, students rather than faculty.*

4. Feelings against inexpensive storage systems run high, yet about a third would be willing to adopt one of the systems at the present budget level. Seating, although less popular as a means of saving money, is also less "unpopular" — that is, it provokes less intense feelings — and may be a superior means of saving money or space. Neither reducing reference personnel or cataloging proved popular.

5. Different groups at M.I.T. prefer different budget allocations. Undergraduates tend to prefer shifting funds from research to reserve, graduate students are more outside-use-oriented (They especially want lower Xerox prices.) and desire increased access to other collections, and the faculty (49 per cent at the $200,000 level) seek departmental libraries. Surprisingly enough, perhaps because of indifference, the faculty are more likely to support inexpensive book storage.

6. Infrequent users of the library (in terms of hours spent weekly in the library) tend to be the most outside-oriented and high users are research-oriented. The library appears now to be oriented toward the latter group.

7. Since there is no relation among major field or department and system preferences, it does not appear that those in the social sciences or humanities are any more dissatisfied or seek a different basic library from those in engineering and science. As the number of non-technical students and faculty rises, there is no indication that the basic nature of the library would have to be altered. The distribution of faculty, undergraduates, and graduate students is more significant.

*Note: The question was whether a second "Student Center Library" should be provided at the east end of the campus.

The third and fourth studies of the year pertained to internal administrative problems which were presented to Fred Wood of Wood and Tower, Management Consultants. The first problem was how to reduce the time lag between selection of a book for purchase and get-
ting it on the shelf; the second was how to reorganize responsibilities in the Director's Office in order to make it more efficient. As in his past work for the Institute, Mr. Wood quickly got to the heart of both matters and made suggestions which have been implemented with excellent results. By having the divisional library prepare the actual order and eliminating pre-order searching, we have saved days in the receipt of books. The Microreproduction Laboratory was brought under the responsibility of the Assistant Director for Technical Services and some further minor changes were made. In the Director's Office a new position, Head of Administrative Services, was created and Lawrence E. Maguire, Administrative Assistant to the Director, was promoted to fill it.

Adapting the Institute's computerized accounting to the Libraries has not been easy but is nearly complete and working well. Mr. Maguire has been responsible and reports as follows:

Administrative Services took a major step forward with the implementation of a new accounting system and financial report format in 1967/68. Much work was done with the Comptroller's Accounting Office to program the system to encompass the myriad inventory details involved in the Library finances. This system worked well in organizing and forecasting our spending patterns. The Librarians used the monthly statements in most cases for control of their accounts. This system also pointed out to the library administration the unexpectedly heavy expenditure pattern in 67/68 and allowed us some control. More important, it gave us time to make adjustments for these heavy expenditures.

Our new system also pointed up a flaw. Years of outstanding orders had created a dollar deficit backlog. We have had no encumbering of committed funds at the time of the order; thus there is a credibility gap between what our expenditure balance reads and what we have committed. We will begin a refined accounting system at the end of July that will take outstanding orders into consideration.

USE OF MATERIALS

One of the recommendations of a student committee which studied the libraries two years ago was finally put into effect this year after approval by the appropriate faculty committees. This was a change in the rules governing the borrowing period for materials. The faculty for years has had the privilege of retaining books for a term; in fact, they were free to keep them as long as they wished since no mechanism existed for requiring their return. Letters were sent at the end of each term requesting the return of items that faculty members were no longer using and these were generally followed by a good response, but a few men kept things more or less permanently.

Partly because of abuses, partly because many believe in the importance of browsing both for work and for pleasure, and above all because students, the major users of the libraries, felt that the old rules dis-
criminated against them, it was decided that all members of the M.I.T. community would observe the same borrowing rules. Unlimited renewals by telephone or in person were to be permitted as long as someone else was not waiting. Overdue notices were to be sent and fines charged to everyone, including faculty and library staff, who failed either to renew or return a book on time. Overdue notices have skyrocketed (32,216 versus 13,266 last year) and fine receipts are up, but as many favorable as unfavorable comments have been received from faculty members. The details of implementation were worked out by a library staff committee under the chairmanship of Miss M. Reay Howie, Rotch Librarian.

This new policy imposes special hardship on a few people who are doing comparative and historical studies and who need to use particular works over a long period of time either to write a book or prepare a class. In anticipation of this difficulty a provision was made for long-term loans in the case of out-of-print books not in demand by others. These loans were to be subject to approval by the Director of Libraries on receipt of a written request from the individual concerned or the divisional librarian. There has been a trickle of these requests throughout the year, perhaps one every two or three weeks, and a somewhat higher number just before the summer, as would be expected.

Another change was instituted this year by faculty vote. As a result of the establishment of the Institute Archives and the decision to deposit the original of each graduate thesis in the Archives, where it will be available for consultation but not circulation, it became necessary for the appropriate divisional library to receive a second copy to go out on loan. Beginning in June, 1968, departments will furnish the original and one carbon of each thesis, or two printed copies.

The Faculty turned down a request of the Director of Libraries with reference to Bachelor's theses. For the last 13 years the departments have been under instructions to select outstanding Bachelor's theses to deposit in the Libraries. What has happened has been that some departments have sent all, some none, and some a few. The Director of Libraries had requested that the departments retain Bachelor's theses for five years, then deposit those which proved to have been valuable, as the basis for an important doctoral thesis, for example. The motion failed. Two copies of selected Bachelor's theses will be transmitted to the libraries.

The most unusual library in our system is that in the Student Center. It is no longer unique, for now the library of the University of Wisconsin at Milwaukee is open 24 hours a day. They, like us, have experienced
enthusiastic response from students. This year 400,000 were clocked into the Student Center Library; 200,000 volumes were reshelved (an indication that much of the use is as a study hall). Average attendance at 3:00 a.m. was 39; at noon, 61, at 10:00 p.m., 188. Minor irritations attendant upon heavy occupancy around the clock, such as litterers and sleepers, continue.

INTERLIBRARY COOPERATION AND OUTSIDE USE

Interlibrary loans were down (2,600 volumes versus 2,899 last year); borrowing was up (1,786 volumes versus 1,495 last year); volumes from which one or more pages were copied were up (22,022 versus 14,121 last year). These are traditional forms of cooperation between libraries. In addition, we have an active exchange program with other libraries here and abroad and an annual published list, *Current Serials and Journals in the M.I.T. Libraries*, which helps other libraries both in learning what is available for loan or photocopy and in building their own subscription list.

The use of the M.I.T. libraries by students and faculty of other educational institutions in the area is considerable. During the year we had occasion to do a study of this use at the request of the U.S. Office of Education. It turned out that from July, 1967, to April 1, 1968, 602 students and 120 faculty members from 109 other educational institutions asked for and received permission to use our libraries on a short-term basis. Many times this number probably used the reading rooms without asking but there is no way of being sure, since at most of our facilities there is no control and anyone with a serious need may consult the materials as long as he does not wish to take them out. In only two of our libraries, where the traffic is heavy and outside requests are numerous, have we been forced to maintain an identification check at the entrance. These are the Hayden Building and especially the Student Center Library, where use is so intense that we are unable to extend any privilege to outsiders.

For a number of years we have had reciprocal use privileges with the Baker, Gordon McKay, and Countway Libraries of Harvard University. To these have been added this year the Wellesley College Library and the Marine Biological Laboratory – Woods Hole Oceanographic Institution Libraries, arrangements reflecting the new close cooperation in educational and research programs between the parent institution and M.I.T.

Industrial and government demands, particularly on the Science and Engineering Libraries, account for substantial activity. Borrower's cards
are issued free to organizations which contribute to the support of the Institute; they are sold to others and to individuals. Following is a five-year comparison of this activity:

**Table IV Borrower's Cards Issued**

<table>
<thead>
<tr>
<th>Membership Plan for Industry</th>
<th>1962/63</th>
<th>1967/68</th>
<th>Per Cent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Liaison and Associates</td>
<td>292</td>
<td>380</td>
<td>30%</td>
</tr>
<tr>
<td>Government Agencies</td>
<td>576</td>
<td>706</td>
<td>23%</td>
</tr>
<tr>
<td>Other Organizations</td>
<td>104</td>
<td>479</td>
<td>361%</td>
</tr>
<tr>
<td>Individuals</td>
<td>6</td>
<td>20</td>
<td>233%</td>
</tr>
<tr>
<td>Total</td>
<td>1,033</td>
<td>1,679</td>
<td>63%</td>
</tr>
</tbody>
</table>

The National Aeronautics and Space Administration (NASA) is included in the above figures but is a special case. This year the Cambridge Electronics Research Center has maintained a staff member in the Science Library. She finds titles desired by NASA staff members and borrows them or Xeroxes selections. Of 3,564 titles requested we were able to supply 3,206. Copies were made from material in various libraries as follows: Science, 972; Engineering, 483; Humanities, 291; Lindgren, 130; and others, 86, for a total of 1,962.

**SPACE**

In general, the space situation in the libraries is critical but not yet catastrophic. A number of libraries are full. Rotch is still taking old material off shelves to make space for new items and can perhaps continue for one more year. Music is in worse shape. It has no old material and there is no place for new records, scores, and books. More shelving will have to be built, reducing seating.

Even more serious than the shortage of shelving is the deplorable physical condition of the Humanities and the Music Libraries. The Reserve Book Room and the Rare Book Room also leave something to be desired physically. Some of these problems come from maintenance too long deferred, which can be explained by the talk of major remodeling which has been going on for two or three years. The temptation has been to postpone repairs but in the meantime the staff and patrons suffer.

In one area, space means space for people instead of space for books. This is in the Technical Services, where materials are ordered, and cataloged, catalog cards are made and filed. For three years this area has been seriously crowded. None of the proposals made for relief have been acceptable. It is our fervent hope that next year will see a solution.
For this program it is best to let Dr. Myer M. Kessler, Associate Director of Libraries for Research and Automation and Director of TIP, speak:

The Technical Information Program (TIP) has emerged from a phase of development and prototype operation of its computer systems into a period of application and production. Much thorough testing provides the basis for further design advance. Project TIP has derived much from its close association with Project MAC, and the constant influence of the computer has insured that the systems constructed are economically sound and sufficiently general. The Library has benefited from a healthy cross-identification of its purposes with the broader data collection efforts of the whole scientific community. During the past year TIP has intensified its study of the management of large data bases, their efficient interrogation, arrangement and internal organization. Since our last report we can mention the following:

1. Progress continues in the transfer of certain TIP functions to the American Institute of Physics (A.I.P.) for national application. Among the cooperative functions undertaken with the A.I.P. are (a) transfer of the data-generation functions. It is expected that sometime in 1968-69 the A.I.P. will produce all the machine-useable data for physics. (b) Two A.I.P. staff members are working with Project TIP personnel to adapt our procedures to their needs. (c) We continue to act as general consultants in the evolution of a National Physics Information Center.

2. At M.I.T. the on-line use of TIP systems is constantly growing. In addition a serious SDI (selective dissemination of information) effort was started with a group of chemists and chemical engineers. This experiment is being closely monitored and may be applied to other groups of scientists.

3. A text management system was organized for a project in the Department of Political Science using TIP programs applied to locally generated data.

4. The application of TIP programs to administrative files and data took a giant step forward with the conversion of several Graduate School functions to TIP operations.

5. In the Library the computer-produced Current Serials and Journals (cs&J) project has been expanded to include a wider operational scope. During the 1967-68 fiscal year, the library staff added over 1,600 titles to the computer files and made more than 1,300 changes to existing entries. Work now in progress will result in a completely automatic system from acquisitions to cataloging. Monographs as well as serials and journals will be covered. A study was made of the integration of our cs&J system with that of Wellesley College. Acceptance of the system by Wellesley is apparently contingent on the availability of funds.

6. Studies are now in progress to evaluate the costs and engineering problems in the production of catalog cards by computer. Initial results indicate that the plan is feasible and will result in the acquisition of machine-useable data as a by-product.

7. A catalog for machine storage and retrieval is being generated as a sub-element of the Science Library. This will serve as a prototype for the evaluation of on-line machine useable catalogs. It is hoped that Steps 5 to 7 will eventually merge into a unified system for the Library.

8. A small grant was acquired with the cooperation of Project MAC, from the National Library of Medicine to explore some applications of TIP to the biochemical literature.

9. A TIP User Station consisting of a computer console, microfilm retrieval unit, and associated equipment has been installed in the Science Library. This station is operational, and in addition to its usefulness for library patrons it is now possible for the librarians themselves to construct moderate-size computer files as special reference tools.
We anticipate a further broadening of TIP applications in the year ahead. Refinement of our designs and adaptation to more generally available computers is under way.

The timing of application of computer techniques to the libraries is good. Accounting is coming under control; the Acquisition and Cataloging departments are eager to begin. Frances R. Lubovitz, Head of the Catalog Department writes, "Our effort to standardize and codify policies is nearly finished so that the next major step lies in the direction of the application of computerized techniques to manual procedures." The Science Librarian, Mrs. Irma Y. Johnson says, "We need funds for machine time on TIP for education and practice by the library staff. With the installation of a TIP console in the Map Room, the Science Library is beginning to receive requests for searches from the readers."

STAFF ACTIVITIES
The professional activities of the library staff are numerous and varied. Members have served in elective and appointive offices, given papers, worked on committees, taken courses, and attended professional meetings. A sampling is listed below.

Laura M. Carchia attended the annual meeting of the Committee of University Industrial Relations Librarians held at Princeton University.

Joseph M. Dagnese returned in December from a year's leave of absence at the Birla Institute of Technology and Science, Pilani, India, where he was Acting Director of Libraries, guiding and strengthening their library. In June he attended a two-week institute on the automation of bibliographical services at the University of Maryland.

M. Reay Howie was a member of the Library Committee of the Boston Architectural Center.

Myer M. Kessler addressed a number of groups on his work in information retrieval during the year. Among these were the American Management Association, The University of Maryland, the Air Force Cambridge Research Center, and the Massachusetts General Hospital.

William N. Locke continued as a member of the Visiting Committee of the Lehigh University Library and was appointed by the New England Association of Colleges and Secondary Schools as a member of the Committee on Evaluation of Wesleyan University. He was Vice President and President-Elect of the National Federation of Modern Language Teachers Associations and attended their annual meeting in Chicago, both in that capacity and as the delegate from the New England Modern Language Association. He was a Councillor, member of the Copyright Committee, and Chairman of the Constitution and By-laws Committee of
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the American Society for Information Science. He was also Chairman of the Linguistics in Documentation Study Committee of the International Federation of Documentation, which will hold its first working session in the fall in Moscow.

Frances R. Lubovitz was Secretary of the Cataloging and Classification Section, Resources and Technical Services Division of the American Library Association (A.L.A.), and served on the Membership Committee of the A.L.A. She assumed the responsibility of Acting Assistant Director for Technical Services in Mr. Dagnese's absence.

William D. Mathews gave several presentations of the Technical Information Program System both here and at other universities. He addressed a seminar on Data Base Construction at the University of Michigan.

James M. Matarazzo was Chairman, Membership Committee, Boston Chapter, Special Libraries Association.

Natalie N. Nicholson moderated two panel discussions, one at the annual convention of the American Documentation Institute in New York, in October, the other at the February meeting of the Boston Chapter, Special Libraries Association. She was a member of the Committee on Cooperation with Educational and Professional Organizations, Association of College and Research Libraries, A.L.A.

Kenneth D. Rude participated in two demonstrations of the Technical Information Program facilities on Alumni Day and lectured to the library staff on Computer Reference and Retrieval Problems.

Peter R. Scott continued as Chairman of the U.S.A. Standards Institute Committee on Microfiches and Micro-opes, and as a member of the editorial board of American Documentation. He served as Papers Chairman for a microphotography symposium held in Boston under the auspices of the Society of Photographic Scientists and Engineers. He also presented several papers.

Patricia M. Sheehan, M.I.T. Representative for the Committee on Library Automation, gave a four-lecture series on computers and the M.I.T. libraries to members of the library staff and guests. She was also a guest lecturer at Simmons College.

The following appointments have been made: Eva M. Bonis, Assistant Science Librarian; Lynne M. Brody, Assistant Rotch Librarian; Nancy T. Chen, Social Science Literature Specialist; Elizabeth G. Flemings, Assistant Science Librarian; Karen Kugell, Exchange and Gifts Librarian; Berna J. Levine, Cataloger; Judith W. Moore, Assistant Humanities Librarian; Lewis H. Morton, Technical Information Project; Suanne N. Muehlner, Assistant Engineering Librarian; Lydia C. Oppmann, Assis-
Lawrence E. Maguire has been appointed Head, Administrative Services. James M. Matarazzo has been appointed Documents Librarian.

Cecile Barsky, Cataloger, and Gertrude Perry, Librarian, have retired.

The following members of the staff have resigned: Drika N. Agnew, Assistant Rotch Librarian; Carolyn S. Argento, Cataloger; Christina M. Chiu, Serials Cataloger; Judith R. S. Greenblatt, Social Science Literature Specialist; Vera S. Hitoon, Exchange and Monographs Librarian; Marshall Lapidus, Cataloger; Faith B. Lederer, Assistant Humanities Librarian; Marie A. Ochab, Assistant Humanities Librarian; Jean K. H. Playfair, Assistant Science Librarian; Alice M. Robrish, Librarian, Materials Center Reading Room; Norbert St. Clair, Cataloger; Colleen M. Scholz, Aerospace Librarian; William H. Scholz, Serials Librarian; and Phyllis M. Sutton, Assistant Rotch Librarian.

The intelligence, the ingenuity, and the enthusiasm with which the staff have served the Institute throughout the year, sometimes under adverse conditions, is a matter of pride to the Director. He is happy to have this opportunity to express his appreciation to them.

WILLIAM N. LOCKE

THE M.I.T. PRESS

The M.I.T. Press, among American university presses, last year ranked behind Chicago, Harvard, Columbia, Princeton, California, and Yale in sales, and for calendar 1967 shared with Yale fifth place in number of titles published (as reported in Publishers' Weekly, January 29, 1968). The Press also enjoyed the positive recognition that produced increased voluntary or unsolicited submission of works for publishing consideration, and the negative recognition of being regarded by one smaller commercial publisher as a pest or even a competitor. The Press staff was paid the professional compliment of being raided by other presses, and its institutional financial support, as measured by indebtedness to its parent, stood at the year's end behind only Chicago, Harvard, and California of the university presses. Clearly, there is much of which we may justly be proud in the record of growth and present achievement of the Press.

HIGHLIGHTS

Yet in summarizing the notable events of this year for The Press, one must begin by laconically noting that whereas we planned and budgeted
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for the publication of 92 new books, we managed in fact to publish only 76: 24 fewer titles than were published last year, ten fewer titles than were published in 1965-66, and two fewer than were published in 1964-65. Numbers of titles published is no measure of excellence, but the ability to plan and execute publication on schedule is indeed a measure of mature and reliable performance. The M.I.T. Press appears less mature in this regard than its external repute would suggest, and than we would have it be.

Of titles in the process of being edited, designed, or manufactured last year, 17 were delayed by the author, either in delivery or return of proof; 26 were delayed by the Press or by book manufacturers serving the Press contractually. Once a title was delayed, it usually ran into further trouble, one title being rescheduled no less than five times, another four times, three thrice, and five twice. All in all, the performance constituted a sobering and in some respects mystifying record. Taken by and large, the major causes of delay may be stated as follows: Authors — There is little one can do to speed an author along unless publication holds direct professional consequence for him. For most of our authors, writing is not their prime concern or skill and their preoccupation with primary or new research vastly outweighs their concern for proper reporting or documentation of research completed. Manufacturers — The significant, though short-lived flow of Federal funds in support of library book purchases, principally by school and public libraries, produced a shock-wave of reprints and rebindings of small editions in 1966 from which our major suppliers have yet to recover. Few have or had expanded sufficiently, in part the result of undercapitalization, in part the reluctance to risk expansion in the uncertain prospect of rapid technological change, particularly in methods of composition and binding. The result has been greatly increased delivery schedules for short-run editions, up to 2,500 copies, and grievous delays once a book falls from an initial schedule. But a third cause of delay is our responsibility solely, and our burden this forthcoming year is to eliminate it. We are not yet skilled in scheduling and holding to schedule our manuscript editing and design efforts. We require better structure and organization in the former, and the development and wide application of standardization in the latter, both in the immediate future. And in the longer term, we must again assess the prospect of bringing composition or one-time keyboarding of the text of our publications back under our direction or even in-house as a production function. Timely and prompt publication of manuscripts entrusted to our professional care must be restored as a prime Press goal.
This major defect alone, however, tarnished a year of very satisfactory achievement. Our sales, despite the loss of one-quarter of our planned-for new titles, held firm; our first-year sales per new book published rose from $7,830 per title in 1966-67 to $8,650; our backlist sales rose from 50 per cent to 60 per cent of our total sales, a highly favorable trend. Our operations, despite loss of anticipated income through delays in publication, controlled adjustment of expenditures, produced a net surplus of $40,133 or 2.6 per cent. Our capital indebtedness to the Institute through substantial reductions in our accounts receivable and manufacturing expense was lowered significantly.

Achievements of note this year included the development and internal adoption of a ten-year operating and capital plan for The M.I.T. Press which in summarized form calls for sales growth of 15 per cent per year, compounded, on title growth of only 5 per cent per year, compounded, yielding estimated annual sales by 1976-77 of $4,780,000, with the publication of 170 new titles in 1976-77, utilizing 97 employees, who will require 12,000 square feet of office space. Approximately 40,000 square feet of warehouse space will also be needed by that date. Two propositions, radical among university presses, were also embraced: In the probable absence of any substantial endowment for the Press to support its capital growth, the plan calls for the Press to earn sufficient operating surplus from 1970 forward, so as to be in a position by 1973 of totally financing its capital requirements for new book inventory. Nonetheless, the Institute would be obliged under the plan to continue to finance short-term indebtedness of Press accounts receivable, as well as the costs of inventory acquired prior to 1973, which would not be totally amortized until 1978, this credit requirement estimated to total by 1976-77, $2,550,000, then as now secured by our inventory and borrowed at interest equal to the rate of income on the Institute's investment portfolio. This plan, approved by The M.I.T. Press Board's Business Committee and ratified by the Board, constitutes an indispensable commitment to and vote of confidence in the prospect of The M.I.T. Press.

Fully integral to the plan for controlled growth in publication is the requirement for physical space for long-term occupancy. The Press has enjoyed an average tenancy in its evolution to date of slightly more than two years. But as an academic community knows full well, moving is disruptive, expensive, and vitiating, and moving every second year destructively so. The quest continued this year for the Press to find a home within walking access of the academic bounds of the Institute. The M.I.T. Press must have another home, if not permanent, then at
least for a decade's orderly residence. The past year saw substantial
gain in this endeavor, but the cost of overcrowding to all operations was
grave, particularly so for the editorial department.

Acknowledging the dominance of journal publication, as opposed to
book publication, in certain research areas, the Press this past year
arranged to assume all publishing functions for the Journal of Mathe-
matics and Physics, shortly to be retitled The Journal of Applied
Mathematics, and laid plans for the development of a journal serving
linguistics and language. Also under active consideration is the develop-
ment of an important new journal in the physical sciences. Journals
developed by the Press will be undertaken or approved for support only
after thorough review and formal approval by the Press' Board, and
then for a term, renewable upon a review of performance. Just as the
Research Monograph Series of publications involved support for indivi-
dual titles, so it is presumed that new journals will require greater
investment than can be recovered from income for a period of three
years. But our hope is for total recovery of direct expense within five
years and a policy that enforces review of both substantive and fiscal
performance at that interval seems wise.

Since it reacquired its backlist from John Wiley & Sons, Inc., January
1, 1963, The M.I.T. Press has stocked all its publications at a London
warehouse, for prompt delivery of orders originating within the United
Kingdom and Europe, and in order to facilitate payment in pounds from
sterling bloc countries. In 1965, the Press became the first American
university press to assign a salaried salesman to Great Britain in ex-
clusive service of our publications. A natural extension of this successful
experiment has now led to the establishment of a sales and promotion
agency arrangement with the University of Chicago Press, the largest
university press in America, and a press with foreign sales roughly equal
to our own. Under the plan, The M.I.T. Press contributed both its sales
manager, to become manager of the shared enterprise based in London,
and its British sales representative, while Chicago has hired one of the
two former European salesmen for the International Book Export
Group (formerly comprising Harvard, Princeton, Johns Hopkins, Corn-
nell, California, and M.I.T.) to sell our books on the continent. This
plan, to which we made a three-year commitment, will enable us to
give intensive direct sales coverage to our publications at a significantly
reduced cost. The University of Chicago Press, with its huge backlist
in the humanities and social sciences, nicely complements our own and
we find in this collaboration the prospect of increasingly effective pro-
motion and appreciating sales in the affected territory.
To the best of my knowledge, The M.I.T. Press alone among American university presses has established a design department headed by a design director, responsible for creating and executing "a consistent and contemporary image to the complete output of The M.I.T. Press." So unusual was the venture, it developed, that two of the three principals involved in setting up the program were invited to address the Boston Bookbuilders on the subject at one of their regular meetings in the fall of 1967. During the first full year of the department's active life it was satisfying to find the Press' advertising mimicked in type and layout, its catalogue design widely copied, and jackets and covers singled out for awards respectively from the Type Directors Club of New York and the American Institute of Graphic Arts (A.I.G.A.) with their Award for Commerce and Industry. That same organization then selected an M.I.T. Press publication as one of the 50 best-designed books published in America this past year.

The A.I.G.A. award-winning design book, incidentally, was also one of the year's best-selling new titles. Written by Allen Forte as a primer for programmers in the language, SNOBOL, the paperback volume was reprinted less than six months after its publication. Clearly the most newsworthy book published by the Press this past year was Dr. David Rutstein's *The Coming Revolution in Medicine*, with more than 5,000 column inches of review and comment in our hands. Yet the book's sales of just over 5,000 copies in its first nine months of publication disappointed us, as did the minority of the reviews with their indications of deeply entrenched individual and institutional rigidities in medical practice and service. If there were an award for the hardest-won successful publication of the year, it would be granted to Andrés Suarez' *Cuba: Castroism and Communism, 1959–1966*, a proper historical account of the rise, digression, and redirection of the Castro revolution by a former participant and present critic. The volume, number 12 in the Center for International Studies' successful series — "Studies in International Communism" — edited by William Griffith, was translated from the Spanish three complete times before a text satisfactory to author and editor could be achieved. Both reviews and sales point to the success of the investment.


We have been holding to a published limit of ten new paperbacks each season, or 20 a year, and now have 90 paperbacks in our numbered...
series, as well as 44 professional and technical paperback editions of standard hardcover works. Last year we sold more than two hundred thousand paperbacks, a highly satisfying result from a series begun a short four years ago. Of titles new to paperback this past year, Douglas Pike's invaluable analysis of and guide to the Viet Cong instantly sold well, and James Q. Wilson's assemblage of reports and manifestos regarding Urban Renewal was a close second in sales. Other substantially sold new titles in paperback were Ray Bauer's timely Social Indicators, commenting on tools and procedures for gathering social data for projective decision making, and Robert Textor's critical valediction to the Peace Corps, Cultural Frontiers of the Peace Corps, several thousand copies of which now constitute required reading in the footlockers of new volunteers. It has been a good year for paperback editions, though a year, as we shall see below, in which the perils of overstocking coupled with competition for bookseller space were clearly visible.

DEPARTMENT SUMMARIES

1. Office of the Director: The M.I.T. Press Board met seven times last year, approving 147 books for future publication by the Press. In support of the Association of American University Presses, The M.I.T. Press last year contributed the services of its Director as member of the governing Board; its Production Director as member of the Association's Production Quality Committee; and its Editor-in-Chief was responsible for the preparation of an intensive program concerned with foreign sales at the Annual Meeting. Miss Barbara Levey, Assistant Editor, submitted a paper at the same meeting on "The Sale of Translation Rights to Foreign Publishers"; she managed the sale of translation rights to 37 M.I.T. books last year, up from 32 the year before.

2. Editorial Procurement: The acquisition of publishable manuscripts continued this past year to be the responsibility of the Director and the Editor-in-Chief, supported by editorial scouting within M.I.T. by W. Joseph Chaput, Assistant Sales Manager, and John S. Snyder, Jr., Salesman, and Joseph Stein, Senior Editor. But all members of the Press staff contribute to editorial solicitation and all department heads and editors have been responsible for the detection or development of at least one new book this past year.

Of the 395 projects received in proposed or final form by the Press in the past year, 247 were declined before reaching the Board, and 25 were declined as a result of Board action. The Board approved 147 and contracts were let for 125 projects. An analysis of projects declined
shows this distribution:

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Sciences</td>
<td>115</td>
</tr>
<tr>
<td>Humanities</td>
<td>60</td>
</tr>
<tr>
<td>Engineering</td>
<td>26</td>
</tr>
<tr>
<td>Science and Mathematics</td>
<td>16</td>
</tr>
<tr>
<td>Architecture and Planning</td>
<td>16</td>
</tr>
</tbody>
</table>

An analysis of manuscripts or projects accepted shows this distribution:

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Sciences</td>
<td>42</td>
</tr>
<tr>
<td>Humanities</td>
<td>23</td>
</tr>
<tr>
<td>Engineering</td>
<td>15</td>
</tr>
<tr>
<td>Science and Engineering</td>
<td>29</td>
</tr>
<tr>
<td>Architecture and Planning</td>
<td>14</td>
</tr>
</tbody>
</table>

An annual inventory of 261 projects pending editorial consideration at the Press, conducted in March, revealed the following profiles by subject:

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Sciences</td>
<td>78</td>
</tr>
<tr>
<td>Humanities</td>
<td>43</td>
</tr>
<tr>
<td>Engineering</td>
<td>22</td>
</tr>
<tr>
<td>Science and Mathematics</td>
<td>64</td>
</tr>
<tr>
<td>Architecture and Planning</td>
<td>54</td>
</tr>
</tbody>
</table>

The same inventory revealed the following profiles by source of project:

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.I.T. Faculty and Staff</td>
<td>54</td>
</tr>
<tr>
<td>Non-M.I.T. Faculty and Staff</td>
<td>109</td>
</tr>
<tr>
<td>Reprint prospects</td>
<td>23</td>
</tr>
<tr>
<td>Translations</td>
<td>57</td>
</tr>
<tr>
<td>Imports from overseas publishers</td>
<td>18</td>
</tr>
</tbody>
</table>

Press monitoring of the editorial potential of the M.I.T. faculty and staff is still deficient; editorial response is too reflexive; and subject coverage is insufficiently comprehensive. At the same time, the Press list of publications reflects satisfactorily many concerns of M.I.T. as a university; the list continues in other areas to anticipate rather than follow curricular trends and emphases, such as visual studies or urban affairs; and last, a satisfactorily high proportion of the books published by the Press are addressed to contemporary national and international social, economic, and political problems and their solution.

3. Editorial Preparation of Manuscripts for Publication: Two younger editors at the Press last year moved on to positions of greater responsibility. Nancy Poling resigned as Assistant Editor to become Editor of Publications for the Center for International Studies; Karla Weatherall resigned as Assistant Editor to become Editor for the Joint Center for Urban Studies. The Press takes pride in their growth and achievement. One new Senior Editor, Thomas McCorkle, was appointed from a back-
The structure of manuscript editing was reorganized to give four Senior Editors, Joseph Stein, Thomas McCorkle, Constance D. Boyd, and Ruth W. Gillies, responsibility for supervising the work of free-lance editors and editorial assistants. Some 19 free-lance editors gave service to the Press last year. Altogether 29,820 pages of manuscript were given approximately 35 minutes of editorial care and repair, per page, at an average cost of $3.38 per edited manuscript page. This substantial investment in bringing an editorial skill to bear on a work, in service both to authors and readers, continues to constitute one of the strongest arguments for publishing a book with The M.I.T. Press. No machine substitute for this process is yet in sight.

The Press makes an extraordinary investment in editorial refinement of raw materials submitted to it for publication, some of which properly should be the responsibility of, and therefore the cost allocated to, the authors. The complexity of text and graphic manuscript copy is enormous. There is real concern for continuing this level of investment for all classes of publication, and the thought in particular is that certain short-lived publications, notably the research monographs and the M.I.T. Reports, deserve less than full editing. But testimonials from authors plus recurring appearance of authors on our list indicate that this present level of editorial investment is noted and appreciated. Costs per edited manuscript page have, incidentally, remained constant for the past three years.

4. Design: As indicated above, the design department, consisting of Muriel Cooper, Design Director, and Lauri Rosser, Design Assistant, has undertaken a most ambitious program, not yet fully realized. When complete, the program calls for (a) the application of standardized design to roughly 80 per cent of our published titles; (b) the total design, inside and out, of the balance of our new publications; (c) the application of the same design ideals and standards to every printed thing emerging from the Press, from catalogue advertisements, and direct mail brochures, to displays for exhibits and labels for our shipping containers and invoices.

At the present time, standardized book designs are not abundant, though about one-fifth of the new books published are receiving full design attention. In addition modular designs for our catalogue, reusable in direct mail promotions, and our advertisements have been established and will be refined through the next few years. Last year 72
book jackets and covers were designed by the design department, several of them, as indicated above, award winners.

A young, highly professional department, the design department nonetheless, until fully realized standardized book designs are accomplished for use on the bulk of our new publications, will be able to service only a minority of our titles, while serving our other institutional needs. For two or possibly three further years, design for the complete output of the Press will not be attained.

5. Production: Not only did the number of new publications decline last year, but the number of titles in process of reprinting or rebinding held constant. The result was a workload roughly equal to levels of 1963-64 or 1964-65. Nonetheless, the lengthening of manufacturing schedules, and the search for new and more prompt suppliers, plus the load of new books in process for publication during 1968-69, and significant staff turnover, made for a busy and in some respects frustrating year. Staff remained constant in number, with Dwight Agner, Assistant Production Manager, being appointed Manager upon the resignation of E. Spencer Qualls Jr., who on July 15, 1968, became Production Manager for Southern Illinois Press. The outlook for 1968-69 is sobering with the budgeting of 100 titles, many of great production complexity, a young staff in terms of book experience, and continuing search for reliable prompt manufacturing.

Operating effectively, although under a reduced load last year, the production department of the Press must this next year (a) assess in-house keyboarding or composition; (b) expand utilization of technological innovations such as film-setting; (c) work toward increased production from camera-ready manuscript copy for photo-offset production.

6. Promotion: The major promotional strategies of The M.I.T. Press continue, as before, with heavy emphasis upon direct mail promotion, last year better supported by space advertising. The object of all promotional endeavor is to bring books published to the attention of their professional or tutorial readers. In absolute terms the effective measure of promotional and sales performance is the net sales return to the Press per promotional and sales dollar expended. The past three years show steady gain — from $4.38 to $4.74 to, last year, $4.90.

The Press relies heavily on the distribution of review copies for unpaid advertising of its publications. The Press distributes from 70 to 150 copies for review of each new title published, in addition to twice or three times this many paperbacks per title for general or non-review promotion. The quantity of reviews is not significant, the quality or
"sellingness" of the review being more important. Nonetheless, the Press last year received about 4,000 review clippings from the reviewing magazines, journals, and newspapers, from its clipping service, and from conscientious authors who spotted reviews. Duplicates of all reviews routinely are sent to the authors and heavy promotional use is made of quotations from reviews.

Newspaper publicity for a newly published book is generally satisfying, if not always redeemable in copies sold. Last year 18 releases covering the publication of appropriate books were sent to professional and technical magazines and periodicals; 17 books were supported by general press releases to newspaper departments other than the book pages; and one title, the Rutstein, was given a major publicity campaign with measurable results.

Exhibits at scholarly and professional meetings constitute a stable, ongoing promotional activity. Last year the sales and promotion staff directed exhibits at nine such meetings where direct sales of more than $4,000 were recorded. The Press continued to benefit by participating in the cooperative exhibits program operated by the American University Press Services, submitting books to 24 national and international meetings, with direct sales of $2,400. In addition, the Press submitted books for exhibit at 21 more specialized meetings through Combined Book Exhibits Program, Inc.

A significant change in emphasis in the Press policy regarding space advertising last year produced 114 ads, at least one appearing in every leading disciplinary publication in fields for which we published books, at a total cost of roughly $25,000. This broad coverage at relatively low cost was made possible by the adoption of a modular ad design utilizing standard typography and layout, into which format list ads for new and important backlist titles could be inserted economically. The cost of space is sometimes less than the cost of preparing an advertisement, particularly in publications of low circulation. The effort, therefore, to minimize preparation costs resulted in much greater coverage.

The backbone of the Press promotional effort was and remains, however, direct mail. Last year the device of a modular catalogue which, taken as a whole, constituted our essential sales tool for libraries, but taken apart, so to speak, became some two dozen ready-made mailing brochures, resulted again in much greater coverage of important markets. In 1967-68, the Press mailed 930,000 pieces of direct mail for roughly the same cost as it mailed 510,000 the year before, thanks to the device of the breakable catalogue. No other single device con-
tributed so substantially to the maintenance of the Press sales as did this instrument.

A very satisfying year featured imaginative embellishment of standard promotional procedures. The promotion department is young, highly professional, and very effective.

7. Sales: As stated before, over-all sales held steady in spite of the substantial loss of anticipated new book income. This was accomplished in the face of three untoward developments, two affecting our domestic sales, the third our foreign sales, and all requiring discussion.

The M.I.T. Press for the past six years has distributed a large number of its titles on publication day through the device of the standing order, an arrangement with leading booksellers here and abroad whereby each of our publications in fields the bookseller selects is shipped to him automatically, without formal order. Over the years the device has worked in a satisfactory manner, particularly abroad, where competent booksellers, knowing their business and stock, weed out and return unsalable titles and rarely overorder. In this country, however, the standing order or agency arrangement had grown rank and weedy, and thus the first job of the sales department was to examine all domestic agencies, cut back the list to those performing well (from more than 200 agencies the list was cut to 142), and to check stock in these and clear out unsold or unsalable books. This clearing of stock resulted in a secondary effect of serious proportions, an increased percentage of returns for the third straight year. Two years ago we were getting back about one book for each 12 shipped. Thanks to agency house clearing, and a much tighter credit check, in this year, we got back one book for each seven shipped, an unacceptably high percentage which must be cut next year. We know we are not overstocking the shops through high pressure sales techniques, because we don’t work that way, nor would our books support such an effort. We also know that we are shipping titles very selectively on standing order. Our deepest fears indicate that the trouble lies in the diminishing reliability of the American booksellers’ own stock control procedures, of literally reordering books without accurate knowledge of stock on hand, and then, at annual inventory, discovering the overstocks which must be returned. It costs the Press about $1.15 to fill an order, plus shipping costs, and about twice that to assess a return shipment and get the books back into our records and warehouse. We cannot afford to service returns of the present dimensions. Our choices are (a) to permit returns of only, say, ten per cent of a quantity ordered by a store; (b) to cut unilaterally an offending store’s order; or (c) working with the worse offenders, trying to set up a stock control pro-
procedure that works. The problem is most acute in college or university towns where a number of stores compete for the sale of supplementary reading books, or non-required, optionally purchased books. Here no store knows what his percentage of the market will be and each overorders in order to be protected, then returns heavily. Last year, for example, the Harvard Cooperative Society, with whose stores we have worked most carefully and closely over the years, ordered $49,641 worth of books from us, and by the end of the fiscal year had returned books valued at $15,698. We must find a solution which is workable, and which we can afford.

On the brighter side, our domestic sales coverage is now rational and effective. Last year our salesmen called on 633 accounts in this country, 413 of which were visited twice, and 131 of which were seen three or more times. Each call resulted in a check of stock, the presentation of a summary of books ordered since the last call (a computer-compiled record which has become an indispensable sales tool) with subsequent discussion of the optimal purchasing procedure for these orders, and a sales presentation of the appropriate new publications for stocking by the store. The results, as backlist sales testify, were salutary.

Foreign sales have always been a sizable fraction of the Press sales, though they were down last year from 25 per cent to 21 per cent of the total. But most recently the risk of selling overseas has increased. The devaluation of the British pound last year cost us $13,000 on receivables payable in sterling; and in India, Indonesia, and the Middle East (particularly Egypt), the market for our books exists, but booksellers simply cannot get foreign currency to buy. The cautionary result is that we may be obliged to hedge our receivables outstanding in soft or threatened currencies, to speed up payments, or even insist upon payment in dollars. This last would seriously reduce our foreign sales at the very time that overseas markets in the form of new college and university libraries are rapidly expanding. The former would involve some speculative hedge such as selling short the currencies involved, a risky undertaking. The present threat is not large, but very real.

Last, mention must be made of a very successful "white sale" of damaged and overstocked titles. We tend to hang onto our books returned as unsold, or books damaged in production or shipment, or books of which we simply printed or bound too many. Elsewhere in the industry such books may be scrapped for paper, or sold to publishers specializing in the sale of such remainders. Last November, the Press held a well announced and promoted clearance sale of such books and managed to realize $14,000 from an average sale price of 35 cents on a
dollar of retail price. The affair was apparently well regarded by the students and faculty of M.I.T. and will be repeated on an annual or biennial basis.

Our domestic and foreign sales programs are sound and are well executed. We have a very competent young, aggressive staff with excellent professional and paperback book sales insight and experience. The only shortcoming is the brevity of trade sales experience and reckoning with several generally salable, non-professional titles this forthcoming year should alter this.

8. Business: This year past saw improved effectiveness in our business operations in part as a consequence, and in part in spite of, substantially changed staff. By absolute measures of the cost of business and warehousing as a percentage of Press sales, the curve is down, from 21.1 per cent in 1965-66 to 20.4 per cent in 1966-67, to 18.1 per cent last year. Work load as measured by invoices rendered was also down from 85,201 in 1966-67 to 73,793 last year which, since it produced roughly the same volume, was also a salutary trend.

Major achievements included a successful assault on our accounts receivable, which as of April 30, 1967, had reached $622,000 or 32 per cent of annual sales, and which by April 30, 1968, had been brought down to $403,000 or less than 25 per cent of annual sales. After applying our reserve for bad debts, the year-end receivables will be $325,000. Nonetheless, work remains to be done, since nearly 16 per cent of the balance carried is more than a year old.

Work simplification devised in cooperation with the Institute’s Auditor has substantially speeded up the work of the accounting department, particularly in the production of operating statements and annual payment of royalties. A revised work schedule making our royalty year April 1 to March 31, and a rescheduling of our dates of annual physical inventory counting so as to precede the year-end accounting chores will also help an entirely new accounting staff get the jobs done more promptly and accurately.

Our warehouse and data processing services are still satisfactorily supplied by Technical Impex, Inc. on a renewed contract. Present calculations indicate, however, that as we reach sales of two million dollars per annum these services will have to be brought inboard. We look forward to this necessity with deep reluctance (warehouse space in the Cambridge area will be costly itself, and difficult to obtain, and the prospect of a remote warehouse with its essential division of Press staff is also unappealing). But contracted warehousing costs about 30
VICE PRESIDENT, RESEARCH ADMINISTRATION

per cent more than one's own, and under our ten-year plan we will scarcely be able to justify the luxury.

The business and warehouse services of the Press are now the most effective we have known. The direction is good and the backup staff is developing well. Our order fulfillment is rapid and stores which once groaned about our then newly computerized way of doing business now bid our salesmen welcome. We shall require more and better cost accounting and statistical controls and our detailed long-term financial planning needs to be broken down to five quarterly budget projections, and then policed. Present staff and department structure should serve the Press through volume increase of up to 50 per cent.

Conclusion: At the close of its sixth year of operation as a fully functioning university publisher, sales per employee of the Press rose from $32,666 the year before to $36,700. We have in prospect for 1968-69 the strongest fall and spring lists in the history of the Press, and the salesmen project sales for the upcoming year at $1,875,000, if we can manage to publish in that year the 100 planned-for titles.

We didn't get done many things this past year that we said we wanted to do. We left for the future any further venture into microform publication, and we signally failed to publish any sight and sound publication of classroom materials, though we did build two such projects into our future. And so our goals for next year continue as stated before, all in support of the publication of as many good books and journals as we can afford.

CARROLL G. BOWEN

OPERATIONS RESEARCH CENTER

The trend in applications is toward concentration in the areas of urban and other public systems. Theoretical work continues in the areas of probabilistic models, mathematical programming, and statistical decision theory.

Several faculty and graduate students at this Center have contributed to the work of Project TRANSPORT on high-speed ground transportation. Operations research techniques have been used to study the queuing, scheduling, and control problems arising in such transport systems. Related doctoral theses in progress are concerned with air traffic control and problems of automobile traffic flow. Professor Ernst G. Frankel of the Department of Naval Architecture and Marine Engineering, who returned from Washington last fall, has carried on work of his own in studies of shipbuilding productivity and unitized cargo loading and has
also been active in the Center's program. He has supervised graduate research in sea transport scheduling and ship loading, part of the Center's contributions in the general field of transport.

Another important area of research is related to specific applications in public systems. Professor Alvin W. Drake is supervising studies in the allocation of police patrol forces, the operation of urban emergency ambulance services, and the design and operation of regional blood banking systems. Ground-breaking reports by Richard C. Larson on police response time and by John B. Jennings on blood banking systems have been published as Center reports and in the appropriate professional journals.

One of the research assistants supported by the Center has participated in work supervised by Professor Robert M. Solow, developing mathematical models for the economic growth of underdeveloped countries. It is expected that this work will be published in the near future. Thesis research was also concerned with long-range economic and marketing forecasting methods. Other research with practical application had to do with operations at the Institute. Theses completed this year included analyses of aspects of Medical Department operations and of planning for the Science Library and the development of a model for educational space planning at the Institute. The work of Professor Philip M. Morse and his students on library operation is finally culminating in a book, Library Effectiveness — A Systems Approach, to be published by the M.I.T. Press in the fall of 1968. Professor Leon S. White has become a member of the team studying the Institute's management system; his experience in operations research techniques will be applied during the coming year to the analysis of resource allocation problems.

The basic mathematical techniques of operations research continue to be developed at the Center chiefly under the direction of Professors Drake, Gordon M. Kaufman, John D. C. Little, Jeremy F. Shapiro, and George P. Wadsworth. Typical problem areas considered during the past year dealt with scheduling algorithms, integer programming, sequential quality inspection, optimization of service disciplines for complex queuing systems, and multinumeraire utility theory.

The staff of the Center, members of six different departments in three Schools, are responsible for teaching most of the subjects related to operations research. Thus, although a graduate student at the Institute may have to choose subjects from different departments and Schools, he can obtain a complete grounding in this field.

The Special Summer Program, "Operations Research for Public
"Systems," is continuing. The Program, to be given in September, 1968, will reflect the growing competence of the M.I.T. faculty in this general field. Scheduled is a dialogue between Professor John F. Collins and the Director of the British Local Government Operational Research Unit concerning urban problems amenable to operations research analysis, in addition to a report by Professor Alan M. Hershdrofer on urban transport systems.

The Center was host to two foreign visitors again this year. F. Kenneth Wright, Professor of Commerce in the University of Adelaide, South Australia, was a guest of the Institute at the Center from October, 1967, to March, 1968; he also spent some time as a consultant with Arthur D. Little, Inc. At the Center he investigated the usefulness of linear programming and duality theory for determining the asset values that should appear in accounting reports. Dr. Anders Martin-Löf was at the Center all year as a Visiting Research Associate, on leave from the Institute for Optimization and Systems Theory of the Royal Institute of Technology in Stockholm. Here at the Center he developed linear programming algorithms for the solution of scheduling problems in transportation, constructed a branch and bound algorithm for minimizing the number of vehicles required to run a shuttle line, and completed a computer program for carrying out the calculations. He also assisted in the teaching of Professor Drake's two subjects.

Professor Morse continues as a member of the Steering Committee of the Joint Center for Urban Studies.

The Center continues to assist its students in locating summer positions which enable them to obtain professional experience in their graduate research areas. During the summer of 1968, John B. Jennings and Richard C. Larson will be members of the Project RAND team working with the administration of the City of New York. Keith A. Stevenson will assist the Health Commissioner of Cambridge to evaluate and improve emergency health services and Joseph Ferreira will work with the Department of Transportation team studying automobile insurance procedures.

Details of the Center's activities outlined above are given in the Center's Annual Report for the year 1967-1968.

PHILIP M. MORSE
ALVIN W. DRAKE

SUMMER SESSION
The 1967 Summer Session was perhaps the most active one since the Summer Session was reorganized in 1950, viewed from the scope of activities and the widespread response from outside M.I.T.
SUMMER SESSION

SPECIAL PROGRAMS

This year, I shall deviate from the usual format of this report by presenting a historical picture of our 18 years of experience with Special Programs for professional men and women from outside the Institute. The historical record of the number of programs and the number of registrants is presented in Table 1.

Table 1 Significant Years in the History of Special Summer Programs

<table>
<thead>
<tr>
<th>Year</th>
<th>1950</th>
<th>1956</th>
<th>1959</th>
<th>1965</th>
<th>1967</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Programs</td>
<td>9</td>
<td>39</td>
<td>26</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>Number of Registrants</td>
<td>368</td>
<td>2,762</td>
<td>1,641</td>
<td>1,569</td>
<td>1,829</td>
</tr>
</tbody>
</table>

There was a steady increase in programs and registrants from 1950 to 1956. By this time, we had canvassed all of the faculty who were interested in giving programs. In subsequent years, the composition of the summer series was based primarily on repeats from previous years, but frequently at two-, three-, or four-year intervals. As a consequence, the total activity declined to a steady operation from 1959 to 1965. During this period, there were always a significant number of programs being offered for the first time so that the series remained very much alive. From 1965 to 1967 there has been another upswing. The 1967 registration of 1,829 people in 38 programs was the highest since 1960.

The composition of the series of Special Programs has changed significantly over the years. The two peak years of 1956 and 1967 will be compared. In 1956, 61 per cent of the programs were offered by faculty from engineering departments, whereas in 1967 the engineering faculty accounted for 45 per cent of the series. More areas of the Institute are now participating so that the summer series is more diversified.

There is reason to believe that the quality of the programs has increased. We have restricted registration to classes of desirable size. In this process, the credentials of the applicants are considered carefully so that registrant groups are now more homogeneous in professional background but still quite heterogeneous with respect to company or government affiliation. Also, we have gained some experience regarding what a prospective registrant expects to gain from a week or two at M.I.T.

CONFERENCES

From June 13 through June 30, 21 people attended a Program in Probabilistic Methods given by Professor Alvin W. Drake under the auspices of the Center for Advanced Engineering Study.
The Ford Foundation supported a conference on Mechanical Behavior of Materials attended by 27 individuals from June 15 through July 7, conducted by Professors Ali S. Argon and Frank A. McClintock.

M.I.T. provided housing and classroom facilities for 21 staff and 80 students of the Bridge Upward Bound Program, directed by Boston ABCD (Action for Boston Community Development Inc.). This was supported by Office of Economic Opportunity funds, and ran from June 27 through August 18.

Professor Frederick T. McGarry conducted a Civil Engineering Materials Workshop for 27 registrants from July 10 through July 21, under the auspices of the Center for Advanced Engineering Study.

The M.I.T. chapter of A.I.E.S.E.C. (Association Internationale des Etudiants en Sciences Economiques et Commerciales) was host to approximately 100 members of A.I.E.S.E.C. from all over the world as well as 25 businessmen and 20 professors. They attended a conference from July 20 through July 23 on "Housing and Urban Redevelopment in the U.S."

Once again, a successful Sensory Aids conference for teachers and students concerned with the education of the blind was held from July 31 through August 11. Forty-seven attended this joint conference with Teachers' College, Columbia University, with aid from the U. S. Office of Education. The late J. K. Dupress of the Sensory Aids Center was the director.

The M.I.T. Christian Science Organization was host to 200 of the Christian Science Group from August 2 through August 4 and to more than 500 from August 23 through August 25.

More than 300 members of the Organization of Arab Students of the U. S. and Canada met at M.I.T. from August 28 through September 2.

M.I.T. housed approximately 320 members attending the International Magnetism Conference in this area from September 11 through September 15. The Bitter National Magnet Laboratory and the Lincoln Laboratory were concerned with arrangements.

In addition, there were eight other miscellaneous conferences housed on campus during the summer.

For the ninth consecutive year, M.I.T. students conducted a Summer Studies Program for talented high school students. Under the direction of Charles Manski '70, 22 college-level courses were taught by undergraduate and graduate students from M.I.T. and surrounding colleges. Courses were in five different fields, three in mathematics, seven in the physical sciences, two in the computer sciences, five in the social sciences, and five in humanities and the arts. This is an entirely voluntary activity on the
part of the instructors, and they were so enthusiastic about the program that it was continued on Saturdays during the regular school year.

REGULAR SUBJECTS

The number of regular academic subjects has remained substantially constant during the past five years. Registration figures are as follows: 1963 — 1,808; 1964 — 1,882; 1965 — 2,090; 1966 — 2,067; 1967 — 2,218.

The increased enrollment since 1963 can be attributed to the expanding size of the Graduate School. Graduate students (1,806) represent 80 per cent of the student body during the summer term.

SERIES IN THE ARTS

During the summer four performances were presented in Kresge Auditorium or the Little Theatre: July 13 — Doraine and Ellis gave a "Costumed Cavalcade of Broadway's Greatest Hits." August 2-4 — M.I.T. Community Players produced two one-act plays: "The Collection" and "Try! Try!" August 11-12 and 16-19 — The M.I.T. Classical Musical Society presented "Li'l Abner." August 23 — Professor Klaus Liepmann conducted an all-Mozart concert by the M.I.T. Choral Society and the Cambridge Festival Orchestra.

In particular, the student presentation of "Li'l Abner" was very well received.

In addition, an Indian Classical Music Performance was held in Kresge Auditorium on the evening of July 8 under the sponsorship of Sangam, an M.I.T. organization for Indian affairs.

JAMES M. AUSTIN
World War II marked a significant turning point in the relationship between the world of ideas and the world of affairs and, in particular, between the universities and the Federal government. With urgent and universal concern for the war effort, the nation needed immediate support, and the universities responded so effectively that the status quo ante has never been recovered. The contributions of the universities to the military strength and security of the United States during World War II and the subsequent Cold War have been so important and so evident that the Federal government also turned to the universities for aid in the space program, which has burgeoned swiftly in this decade.

The three decades of active, large-scale mutual support between government and universities in defense activities, and the shorter span of the space program, have presented challenging administrative problems on both sides. The Institute’s Special Laboratories, the M.I.T. Lincoln Laboratory and the Instrumentation Laboratory, are viable products of this administrative evolution.

Today there is widespread public interest in a broad spectrum of increasingly diverse socio-economic problems — urban affairs, transportation, population, poverty, medical care, pollution, and the like. None of these problems are new in themselves: What is new about them is the extent and immediacy of popular and political concern for visible, substantive progress toward solutions. Each has its technological aspects, but these are generally subordinate to the more complex social, political, and economic considerations — considerations that were less evident in the technologically oriented defense and space programs.

Increasingly large numbers of university faculty are coming to grips
with these problems, within the government itself, as consultants, and as supervisors of academic research activities. There is sharp and searching debate among faculty and students as to the proper role of the university in public affairs, and as to the sometimes conflicting responsibilities of the university to the world and to itself and its student body. There is equally sharp public debate over the appropriate allocation of national resources among security, space, and socio-economic problems, foreign and domestic.

M.I.T. has been a unique contributor to government needs in the physical sciences and technology. We have an impressive history as a constructive and innovative institution. We need to continue to think through what our mission is and can be. It is not yet clear whether organizations like our Special Laboratories are appropriate instruments for the solution of the socio-economic problems that loom so large in the public eye today. However, it is clear that the national security problems for which they were created have not vanished, and indeed that they may not even be significantly altered in scale.

The Institute will continue, of course, to examine the programs and the character of these Laboratories in the light of our primary responsibilities in education and academic research, mindful of the special contribution that we can and must make to the national welfare.

The reports which follow, by the Directors of the Lincoln and Instrumentation Laboratories, testify to another year of significant technological achievement by each Laboratory. The year was also, however, one of funding uncertainties for both Laboratories in a climate generally unfavorable to government research programs. In all probability the year ahead also will be difficult, because this report is being written shortly after the enactment of legislation requiring a six-billion-dollar cut in Federal expenditures during fiscal year 1969. At present there is not enough information to predict the impact of this cut on our Special Laboratories, but we are confident that they will weather the difficult period ahead and maintain their outstanding quality.

Last year we expressed a concern about the inclusion of the Lincoln Laboratory in a category called Federal Contract Research Centers (FCRC), a Department of Defense term encompassing not-for-profit organizations of widely varying character and mission. Such a broad categorization tended to submerge the substantial differences that exist between a university laboratory like Lincoln, and such independently managed organizations as the RAND and Aerospace Corporations. Increasing Congressional concerns about certain aspects of FCRC operations and practices were reflected by a substantial cutback in the
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appropriations request to fund these organizations during fiscal year 1968. The final impact of the cut on the Lincoln Laboratory was less severe than anticipated, but we have felt that it is important that the Congress and the public be informed about the differing nature of these organizations.

This point of view was communicated to the Department of Defense and accepted as valid. We are gratified that Secretary McNamara, in his statement to the Senate Armed Forces Committee on the Fiscal Year 1969 Defense Budget, classified the nine largest FCRC's into three well-defined categories. The Lincoln Laboratory and the Johns Hopkins Applied Physics Laboratory were described as specialized research groups in the physical sciences. The MITRE and Aerospace Corporations were described as Air Force systems engineering organizations. The other five (IDA, RAND, Research Analysis Corporation, Center for Naval Analyses, and Analytical Services, Inc.) were described as essentially operations and systems research organizations.

We continue in our conviction that the Institute benefits from interactions between the Special Laboratories and the academic departments, and we are pleased to note that in the past year such interactions have increased. Two specific examples, further detailed in the individual reports that follow, are the Seismic Data Center being established jointly by the Department of Geology and Geophysics and the Lincoln Laboratory seismic discrimination group, and the Instrumentation Laboratory's new Division of Scientific Technology, which is already active in joint research efforts with several M.I.T. departments and with other organizations such as the Harvard School of Public Health and the Woods Hole Oceanographic Institution. In addition, as separately reported, both Laboratories have contributed staff to teaching activities, have provided research and thesis facilities for faculty and students, and have availed themselves of the educational opportunities at M.I.T. and other neighboring academic institutions.

An interlaboratory exchange of particular significance took place as C. Robert Wieser, Deputy Director of Lincoln Laboratory, accepted Dr. C. Stark Draper's invitation to take on the additional responsibility of coordinating the APOLLO software effort as a Deputy Director of Instrumentation Laboratory, in collaboration with Ralph R. Ragan, the Deputy Director for National Aeronautics and Space Administration (NASA) programs. Mr. Wieser brought to the Laboratory an outstanding background in the delivery of large-scale, special-purpose systems programs dating from his work on the SAGE system developed by the Lincoln Laboratory. The combination of Mr. Wieser's experience and
that of the Instrumentation Laboratory staff members associated with the effort brought software delivery schedules in line with hardware schedules.

Finally, we wish to note that both Laboratories are becoming involved on a modest scale in contributing to the solution of problems other than those with which they have been concerned traditionally. Transportation, medical care, and environmental control problems are getting increasing attention nationally, and staff members of both Laboratories are enthusiastic about finding ways to apply their experience to these areas. It is expected that such involvements will continue to remain relatively modest in the foreseeable future. However, if the nation's commitment to solving such problems matches its increasing concern about them, M.I.T. Laboratories have the dynamism to adapt their unique talents to research in these areas.

JACK P. RUINA

INSTRUMENTATION LABORATORY

Support for sponsored research in the Instrumentation Laboratory increased by slightly over 8 per cent during the 1967-68 academic period as compared with the previous year, the current yearly rate being approximately 53 million dollars. Total personnel, including associated laboratories and industrial assistance, was at about 2,500 on April 1, showing an upward trend of just over 7.5 per cent within the last year.

Education for the full spectrum of students, from undergraduates through graduates and postgraduates concerned with bridging the gap between academic studies and professional practice, has continued to be a major concern of the Laboratory. This activity, as in past years, was made very effective by the long-established position of the Laboratory as an integral part of the Department of Aeronautics and Astronautics. During April, 1968, about 375 students ranging from freshmen to candidates for doctoral degrees were associated in some significant way with the Laboratory. During the same month 90 members of the Laboratory staff were enrolled as Special Students at M.I.T. and 81 others were taking courses at outside schools. During the year 42 students carried out thesis work in the Laboratory under the supervision of faculty members and staff engineers. Of these students, 22 accomplished research at the doctoral level, 16 worked on Master's theses and four concerned themselves with Bachelor's theses. A total
of 26 degrees were granted at the June graduation to members of these groups.

In addition to providing facilities and teaching help for regular academic activities, the Laboratory employed 144 students in part-time work during April, 1968, a typical month.

Classification of reports and equipment produced by the Laboratory is involved in about 20 of the 40 existing contracts. It is usual for these contracts to contain provisions allowing access to pertinent restricted information and specifying certain limited categories of data and design results that must be subject to security regulations. In practice, classification has interfered very little with educational activities of the Laboratory. For example, out of 19 theses accepted during a typical period between January and June, 1967, only one was classified. Among Laboratory reports issued during the first four months of 1967, a representative sample numbered 69, of which 21 were classified, seven as secret and 14 as confidential. The total number of pages involved was 3,641, of which 11.3 per cent were classified. Considering both the Laboratory reports and academic writing of some 6,700 pages, classification was involved for only 6.5 per cent. As a matter of general policy, all classified material is reviewed at intervals and cleared as soon as this action is possible.

In practice, all results from work in the Laboratory are systematically reduced to scientific and engineering generalizations in terms suitable for educational purposes. This method of operation effectively eliminates difficulties in the teaching of basic information that is developed during classified projects while retaining the benefits of adequate support in facilities and funds that would not be available except for the powerful motivation and funding generated by requirements of national defense. The experience of more than 30 years shows that engineering education can be effectively carried on in an atmosphere of creative technology involving a reasonable amount of classification. Instrumentation Laboratory operations and educational activities are not affected to any significant extent by classification. The Laboratory holds to the principle that classification is not desirable in itself and is to be minimized or eliminated whenever possible. However, the situation is now generally satisfactory and the Laboratory does not intend to request any changes.

Faculty members of the Department of Aeronautics and Astronautics have continued to provide general direction for Laboratory activities and to incorporate information and experience derived from developments of advanced technology into the body of engineering education. Institute
Professor Emeritus Charles S. Draper continued to serve as the Laboratory Director, with Professor Walter Wrigley as Educational Director. The group of Department faculty members associated with Professor Wrigley in academic activities included Professors Yao T. Li, H. Philip Whitaker, Winston R. Markey, Wallace E. Vander Velde, Robert K. Mueller, Laurence R. Young, James E. Potter, Jacob L. Meiry, and Walter M. Hollister. From the Laboratory staff Dr. Ramon L. Alonso, Dr. Richard H. Battin, Dr. Elmer J. Frey, Dr. John Hovorka, and Dr. Robert G. Stern all served as lecturers, taking responsibility for teaching subjects in Aeronautics and Astronautics. Roger B. Woodbury, Forrest E. Houston, and Ralph R. Ragan continued to serve as Deputy Directors with Joshua B. Feldman as executive officer.

Since the beginnings of its precursor group almost 40 years ago, the Instrumentation Laboratory has cooperated with scientific and academic activities within and outside M.I.T. whenever this cooperation has been desired and could be effective. The continuing effort with Professor Edward W. Merrill of the Department of Chemical Engineering toward the development of viscometers for blood analysis is but one example of many joint projects. In past years, research of this kind has been encouraged wherever it has appeared, but no special provisions existed for searching out significant problems or for stimulating new activities inside or outside the Laboratory. This situation has been changed during the past year as a result of the inspirational interest and effective work of Laboratory staff member Philip N. Bowditch in helping various non-Laboratory groups with the engineering and the construction of apparatus needed in carrying out their projects. As a means of giving Mr. Bowditch the recognition and status consistent with the importance of his efforts, he has been appointed Director of the Division of Scientific Technology.

This new division devotes its efforts to the engineering, design, construction, testing and operation of apparatus and systems needed for research in pure and applied science. Emphasis is on assistance for projects conceived and directed by M.I.T. faculty members, not necessarily of the Instrumentation Laboratory, who may be working either alone or in cooperation with scientific organizations outside the Institute. The division is now assisting the Center for Earth Sciences and the Woods Hole Oceanographic Institution in the design, construction and installation of a sensor network for collecting information on flow, temperature, salinity and other conditions within selected bodies of ocean water. Various new projects are either in progress or being formulated.

Mr. Bowditch's division is enthusiastically accepting its responsibility
for determining, defining and exploiting complementary areas of cooperation for the Laboratory and the scientific community. A number of possibilities now being discussed are expected to result in significant and interesting future projects.

The primary concern of the Instrumentation Laboratory is pioneering technology which generally deals with all phases of significant systems from their beginnings in imagination, through theoretical design, engineering design, engineering testing, production documentation, production, and finally operational use. On the basis of some 40 years of experience, it is apparent that over-all performance limitations generally reside in basic sensors and computing systems. Computers for flight vehicle applications have long been an important part of the Laboratory efforts with a degree of effectiveness that is illustrated by the success of POLARIS and APOLLO systems for control, navigation and guidance of submarines and of spacecraft. The general usefulness of over-all systems based on developments of this kind is made clear by the current introduction to civilian transport operations of industrially manufactured inertial navigators based on principles first conceived and reduced to practice by the Instrumentation Laboratory.

One of the most significant tasks now in progress is that of developing greatly improved inertial quantity sensors under a planned three-year program for the Electronics Research Center of the National Aeronautics and Space Administration (NASA). This program is directed toward the realization of angular deviation receivers based on single-degree-of-freedom gyroscopic units and of specific force integrating receivers using gyroscopic rotors as calibration elements. Both instrument types are being given new embodiments with two orders of magnitude better performance and at least one order of magnitude longer life than good instruments of today. It is expected that development of the new sensors will be complete, with engineering information available to start prototype design and the documentation of manufacturing information within about 12 months. Production with new mechanized assembly and adjustment methods and equipment is a goal for one year later.

When the new sensors become available in quantity, control, navigation, and guidance systems having inertial performance characteristics that will revolutionize submarine, aircraft, missile and spaceship operations will become realities. When this occurs during the years ahead, the Instrumentation Laboratory will be credited with another great contribution to the technology of modern transportation.

Significant developments occurred in substantially all the system technology programs of the Laboratory during the 1967-68 academic
year. Flight testing of the APOLLO guidance and navigation system has gone forward with two unmanned flights. One launch with only a Lunar Excursion Module aboard was not completely successful, but did provide results showing that the Laboratory guidance and navigation system worked without fault so far as the existing configuration would allow. The second SATURN V launch with the Instrumentation Laboratory system in a command module had difficulty due to rocket engine malfunctions, but demonstrated that the guidance and navigation system operated with performance well above specification requirements. The system that will fly next fall in the first manned test of the APOLLO system is now ready and operating at satisfactory levels.

The APOLLO guidance and navigation system hardware is not only designed, but the units required are far along in manufacture so that equipments are now waiting for flight operations. The Instrumentation Laboratory work on APOLLO hardware remains at the relatively low level needed for testing and product improvement, but the development, realization, and testing of software appears to require substantially the present level of activity for at least one and probably more years into the future.

Work for the United States Navy on guidance for the POSEIDON Fleet Ballistic Missile System has progressed through design and preliminary production stages with flight tests expected early in 1969.

Stabilization and control for the Orbiting Astronomical Observatory (OAO) telescope project of NASA has been completed from the standpoint of design and is now being produced in the limited quantity needed for OAO operations. Laboratory testing is in progress and the first flight is expected early in 1969.

Control, navigation and guidance for the Navy's Deep Submergence Project (DSP) has been designed and built and is now in the process of being delivered to the first test vehicle. The problems associated with DSP hardware still require concentrated attention, but software development and production activities must receive major efforts during the months ahead.

The SABRE ballistic guidance system for the United States Air Force has been built from Instrumentation Laboratory designs by the Laboratory itself, by the A-C Electronics Division of General Motors, and by the Autonetics Division of the North American Rockwell Corporation. Laboratory and centrifuge tests of these prototype systems have demonstrated that they meet the accepted performance goals. Test work and advanced design is continuing with the objective of having technology ready when decisions are made with regard to future applications of the
SABRE system. It is hoped that support will be available for design studies of improved equipment based on new sensors and electronic systems.

Radiation field pattern plotting studies have been interrupted by a delay in funding from the Federal Aviation Administration. The equipment needed for accurate plotting of these fields has been designed and built. Work is now being started again with Laboratory check-out tests before flight installations are made.

VTOL (Vertical Takeoff and Landing) and helicopter control, navigation and guidance work for the U.S. Army and for the Electronics Research Center of NASA has been proceeding slowly because of low support levels. The basic importance of this work is generally recognized, especially as it is closely associated with educational interests in the Department. Every effort is being exerted to keep the VTOL-helicopter work alive until its significance is recognized and proper support is made available.

In the present time of generally curtailed support for research, engineering and technology, the Instrumentation Laboratory continues to hold its position of preeminence among organizations dealing with the frontiers of technology in the field of control, navigation, and guidance. It appears that funding support for the coming year will be reduced by 20 to 25 per cent. This reduction, which requires some difficult decisions, will not prevent the orderly continuance of the Laboratory's activities.

C. STARK DRAPER

LINCOLN LABORATORY

On July 26, 1968, Lincoln Laboratory completes its 17th year of operation. Formed for the purpose of creating effective solutions to urgent national air defense problems, the Laboratory has made major contributions to the three air defense and early warning systems now in operation (SAGE, the DEW Line, and the Ballistic Missile Early Warning System). We are continuing to apply our competence in radar, data systems, communications, and advanced electronics technology to current defense problems, with principal emphasis on ballistic missile penetration and discrimination and military satellite communications.

ACADEMIC INTERACTIONS

Lincoln plays a significant role in bringing important technological problems to the attention of university scientists and engineers who are
striving to roll back these frontiers through science and education. The extent of this mutually beneficial interchange between the academic community and the Laboratory’s technical work for its sponsors is difficult to measure exactly, since it covers such a broad range of interpersonal and organizational activities, formal and informal. During the last 12 months, Lincoln has received more than 2,500 visits from faculty members and students representing more than 70 different academic institutions. In addition, there were more than 1,700 visits by consultants, many of them faculty members, and at the present time we have some 50 faculty members and graduate students on our regular summer staff.

During the past year, 33 students used Laboratory facilities for theses at the doctoral level. In the reverse direction, 121 Lincoln personnel completed subjects at the undergraduate or graduate level under the M.I.T. Tuition Assistance Plan.

Dr. Irwin I. Shapiro was appointed Professor of Geophysics and Physics at the Institute; he is continuing his work at Lincoln on a part-time basis. Dr. Mildred S. Dresselhaus of our Solid State Division was appointed Abby Rockefeller Mauzé Visiting Professor in the Department of Electrical Engineering for the fall term; she is the first woman to hold a professorship in this Department.

PROFESSIONAL ACTIVITIES

The Laboratory’s close and important ties with the professional community and technical industry may also be highlighted in several ways. Members of the Laboratory published 180 journal articles and presented 467 papers at professional society meetings this year, and three books by Lincoln authors were added to our Lincoln Laboratory Publications series: *Radar Astronomy, Switching Theory,* and *Thermoelectric and Thermomagnetic Effects and Applications.* In this same period, there were 13,646 visits to the Laboratory by personnel from more than 1,100 different (though not necessarily independent) companies, not counting subcontract personnel resident at the Laboratory or routine service calls.

Dr. John B. Goodenough of our Solid State Division was honored jointly with Leopold Senghor, President of Senegal and generally considered to be the greatest living poet in the French language, as Docteurs Honoris Causa representing the Sciences and the Arts, respectively, at the dedication of the new Talence-Pessac facility of the University of Bordeaux.
Our Seismic Discrimination Group, which is developing techniques for detection and identification of underground nuclear explosions in the Vela Uniform project for the Advanced Research Projects Agency (ARPA) (see below), has been working increasingly closely with the Department of Geology and Geophysics, blending competences in applied communication theory and classical seismology. Lincoln has provided data, from large seismic arrays in Montana and Norway, that have been used for a number of student and faculty research projects, yielding several doctoral theses and publications. We have two Research Assistants from this Department, and we help to administer a joint ARPA postdoctoral fellowship program. To facilitate this collaboration and to use our joint resources to best advantage, the Department, Lincoln, and ARPA have worked out a plan for a Seismic Data Center in Cambridge to house the entire Lincoln group, ARPA Fellows, several faculty members and a number of students, with Lincoln-generated seismic data files and computation and display facilities. This center will go into operation during the coming year.

Lincoln Laboratory is also participating in efforts to provide radio and radar astronomy facilities for the New England scientific community. With M.I.T., Harvard University, and the Smithsonian Astrophysical Observatory, Lincoln Laboratory was a member of the Cambridge Radio Observatory Committee (CAMROC), which developed the scientific definition and engineering design for a major new facility, with a radome-enclosed antenna 440 feet in diameter, to be located in the New England area. A proposal for this facility, submitted by CAMROC to the National Science Foundation (NSF) in early 1967, was favorably reviewed later in the year by an NSF Advisory Panel for Large Radio Astronomy Facilities, with the recommendation that its merits should be compared with those of large, fixed, spherical reflectors like the Arecibo antenna in Puerto Rico.

In July, 1967, the Northeast Radio Observatory Corporation (NEROC) was formed, supplanting CAMROC, to develop a new regional radio observatory in the Northeast, with Professor Jerome B. Wiesner of M.I.T. as Chairman and Professor Edward M. Purcell of Harvard as Vice Chairman. Twelve colleges and universities and the Smithsonian were initial members of the new non-profit corporation. A detailed engineering comparison study, as suggested by NSF, was completed in March, 1968. It demonstrated that the NEROC design is the more attractive solution, for microwave operation, from both a scientific and an economic viewpoint.

A two-volume report of new engineering studies for the proposed
NEROC facility was completed on June 30. These very extensive engineering design studies have been directed by Lincoln Laboratory and sponsored by the National Science Foundation with assistance from the Air Force, with substantial participation and contributions from faculty and students in the Department of Civil Engineering and the Department of Aeronautics and Astronautics. At the same time, our own Haystack and Millstone facilities are being used ever more extensively by Harvard and M.I.T. faculty and students. Pending definitive action on the proposal for the new facility, Lincoln Laboratory is cooperating with NEROC in the preparation of a proposal to NSF for a transformation of Haystack into a regional observatory under university management; as presently visualized, this transfer would take place gradually, over a period of several years, with substantial Lincoln support continuing during that period.

We have devoted some time and effort to the exploration of possible future Lincoln Laboratory programs in non-defense areas. Negotiations have been completed for a program to design a prototype Ambulatory Health Care System for the purpose of demonstrating a possible mechanism for upgrading national health care. This program, financed by the Commonwealth Fund, will be carried on in cooperation with representatives of the Cambridge Department of Health, Hospitals, and Welfare, the Harvard Medical School, Massachusetts General Hospital, Beth Israel Hospital, and the M.I.T. Medical Department.

CHANGE IN PROGRAM SPONSORSHIP

During the early part of the year, funding uncertainties required considerable time and effort. A decrease in Air Force support necessitated a 3 per cent reduction in personnel. Funding for the coming year is still not completely settled. Major attention has been devoted to plans for adjustments to sponsorship changes in our ballistic missile effort. The decision by the Federal government to deploy an antiballistic missile defense system will result in the coming year in the transfer of a substantial portion of the Laboratory's effort in missile defense from the Advanced Research Projects Agency to the U.S. Army. The Army has been given the responsibility for further research and development as well as deployment of this system. In a related move, responsibility and support for the Laboratory's current Project PRESS (Pacific Range Electromagnetic Signature Studies) instrumentation on the Kwajalein Atoll will be transferred from ARPA to the Kwajalein Missile Range in the National Range Division of the Department of Defense. During the last six months we have devoted much time and thought to planning for an effective
adjustment to these changes, which will occur during the coming year. In recognition of the forthcoming participation in the Laboratory's technical program by the Army, Lieutenant General Austin W. Betts, Chief of Army Research and Development, has been appointed a member of the Joint Advisory Committee. The other members of this Committee, which provides over-all policy and program guidance to the Laboratory, are General James Ferguson, Commander of the Air Force Systems Command, who serves as Chairman, and Dr. Eberhardt Rechtin, Director of ARPA.

**SCIENCE AND ENGINEERING**

During this academic year, the Laboratory has made significant progress in its technical projects and programs. Some examples of this progress, which will be discussed in more detail below, include the LES-5 communications satellite and the Tactical Transmission System (TATS) for communication via satellites, the ALTAIR (ARPA Long-Range Tracking and Instrumentation Radar) and ALCOR (ARPA-Lincoln C-band Observables Radar) radars and the Airborne Infrared Telescope (AIRT) for re-entry measurements, the IBM 360/67 computer system, advances in infrared laser and solid-state detector technology, and a validation of the fourth test of general relativity theory by radar.

Lincoln Laboratory's major efforts are centered in two fields: space communications, and re-entry technology pertinent to ballistic missile penetration and discrimination. Continuing attention, on a considerably smaller scale, is directed to seismic discrimination of earthquakes and underground nuclear explosions and to computer graphics. Additional projects include the further development of communication techniques for command and control of Navy submarines, radar techniques for the detection of personnel and vehicles in foliage, and radar techniques for underground tunnel detection. These projects receive technical support from a program of general research in solid-state, data systems, integrated circuits, radio physics, and radar. In addition to its in-house research and development activities, the Laboratory continues to provide technical advice, guidance, and support to government agencies on various other programs and activities.

**SPACE COMMUNICATIONS**

The Lincoln Experimental Satellite LES-5, developed in the Air Force-sponsored Space Communications Program and launched on July 1, 1967, has clearly and repeatedly demonstrated the feasibility of direct, dependable communication via satellite, over long or short distances, among compact surface terminals with antennas small enough to be
mounted on individual vehicles. Soon after launch, a triservice test plan realized the first direct teletype communication via satellite among Army, Navy, and Air Force units, including ships and submarines at sea, aircraft in flight, and mobile and portable ground stations. Subsequently, these experiments have spanned transoceanic and transcontinental distances, from the Mediterranean to the far reaches of the Pacific, with results that have evoked warmly enthusiastic responses from the users and other interested agencies.

Operating at frequencies in the so-called UHF-band, which extends from 225 to 400 MHz and is used for a wide variety of government communication assignments, LES-5 communications are highly resistant to any interference from weather disturbances or electrical storms. The LES-5 antenna system produces circularly polarized radio waves that can be picked up by small terminal antennas without the fading and drop-outs that might otherwise be caused by Faraday rotation.

The first airborne tests of the Lincoln-designed TATS were conducted this spring between the Laboratory in Lexington and an Air Force C-135 near Guam some 8,100 miles away, with LES-5 over the Marquesas Islands off the west coast of South America, almost on the horizon for both surface terminals. Clear, error-free teletype messages were exchanged between the two terminals, and the aircraft also demonstrated the feasibility of air-to-air satellite communication using a blade antenna less than a foot long projecting from the top of the aircraft. Designed for both teletype and vocoded voice transmission, TATS uses a frequency-hopping modulation technique that provides substantial protection against natural or man-made interference and at the same time permits many terminals to use the satellite simultaneously: TATS makes LES-5 available to 20 or more simultaneous users. Additional TATS units are under procurement by the Air Force for multiple-user triservice tests.

The next experimental satellite, LES-6, scheduled for launch later this year, is a much more sophisticated, synchronous-orbit UHF-band satellite, with substantially greater power and capacity than LES-5, in combination with a number of new station-keeping, orientation, and propulsion systems. LES-5 and LES-6 provide valuable practical operating experience to pave the way for the operational Tactical Communication Satellite currently under procurement by the Air Force.

BALLISTIC MISSILE PENETRATION AND DISCRIMINATION

There are three interrelated parts to this program, which was formerly called Re-entry Technology. Taken together, they make up the Laboratory's largest single area of effort.
The Laboratory is scientific director for ARPA of Project PRESS, which is aimed at achieving a better understanding of phenomena associated with ballistic missile re-entry into the earth's atmosphere. Continuing improvement in the extensive measurement facilities on the Kwajalein Atoll and on the instrumented KC-135 aircraft has yielded substantial increases in the quality and quantity of the data obtained from full-scale re-entry tests. Two large new radar systems to augment and extend the resolution and frequency coverage of the existing TRADEX radar are nearing completion on Roi-Namur Island. The first is the ALTAIR system, for which the Laboratory has served as technical advisor to ARPA and has designed and built a unique digital data processing and recording system. The second is the high-resolution ALCOR system, designed and built by Lincoln Laboratory; this system includes a digital computer that controls all radar operational and data-handling functions, including automatic checkout and system calibration, yielding unusual flexibility and savings in time in radar operations. The PRESS field measurements are coupled with a correspondingly substantial data recovery, analysis, interpretation, and distribution effort at the Laboratory in Lexington, and supported by theoretical studies and by laboratory measurements in the Re-entry Simulating Range.

The second part of our Ballistic Missile program, also sponsored by ARPA, is designated Radar Discrimination Technology. Extensive analysis and engagement exercises have been used to analyze radar functions in ballistic missile defense systems and to study the strengths and weaknesses of modeled radar responses to advanced penetration systems. The ALCOR radar had its origin in this program, and Lincoln is continuing to serve as technical advisor to ARPA in the development of the Advanced Design Array Radar (ADAR). Studies are being made of cost comparisons of various phased array configurations, to develop a model for cost minimization of such radar systems for specific functions, and of certain important new components and techniques, such as integrated microwave circuits.

The third part of our work related to ballistic missiles is the Air Force-sponsored Re-entry Systems Program, to aid in the development of new and improved re-entry vehicles and penetration aids for U.S. weapon systems; this program was formerly called Ballistic Missile Re-entry Systems (BMRS). Areas of major effort and accomplishment are test planning and instrumentation, re-entry data analysis, data techniques development, penetration systems research, and electronic countermeasures.
VICE PRESIDENT, SPECIAL LABORATORIES

VELA UNIFORM

This project, under the sponsorship of the Advanced Research Projects Agency, is concerned with the development of methods for the seismic detection, location, and identification of underground nuclear explosions. A major source of seismic data for this program has been the Large Aperture Seismic Array (LASA) in southeastern Montana, with some 600 seismometers distributed over an area 200 kilometers in diameter. Continuing responsibility for the operation and maintenance of this array has now been transferred to the Air Force Electronic Systems Division, but the new M.I.T. group mentioned earlier will continue to collect and analyze data from LASA and from other sources, with special emphasis on the further development of techniques to distinguish underground explosions from earthquakes of comparable magnitude.

Another array is presently under construction in Norway, where it will be operated by the Norwegian government as a seismological research instrument. The Lincoln group played a substantial role in the preliminary design of the new array, based on operating experience with LASA, and will continue to provide such technical advice and assistance as may be needed for its installation.

GENERAL RESEARCH

Our Air Force-sponsored programs of general research are a vital source of the new ideas that are constantly needed to maintain and replenish our competence and effectiveness in dealing with practical problems. This year has seen noteworthy developments in work on data systems, solid state, and radio physics; in many instances, we have achieved significant new objectives in continuing programs of several years duration.

We have begun to realize in full measure the capacity, versatility, and efficiency of our IBM 360/67 computer, the first installation of this new system, which reflects in its design many features that were called for in an earlier Lincoln specification for a new central computer facility. The time-sharing system is in regular operation nine hours per day, typically serving 25 to 30 simultaneous users. There are now 54 terminals and more than 90 user accounts throughout the Laboratory. Along with the individual users, the multiprogramming capability of the 360 system permits on-line acquisition and processing of experimental data, such as solid-state spectrometric measurements or tests of LES-6 satellite sub-systems. One “user” is a channel for batch processing that operates in the time-sharing environment with twice the efficiency that is normally achieved in conventional production runs.
Our TX-2 computer facility continues to serve as a vehicle for advanced research in computer hardware and software. Now installed and operating in TX-2, side-by-side with conventional core memory units, is a million-bit memory module that stores 12,500 bits per square inch, using magnetic film deposited, scribed, and etched integrally with electrically conducting word lines on glass substrates. The fabrication and testing techniques that made this memory possible were developed over several years past in an effort to reduce significantly the cost of the basic storage medium: In this case, estimates of 0.1 cent per bit are based on limited laboratory production.

TX-2 has also been the vehicle for the development of coherent programming techniques that have yielded a library of programs that are fully and directly compatible with and accessible to one another, a commonly accepted but seldom achieved goal of program libraries. A new language has been developed that greatly simplifies the production of programs for special graphical systems.

Our work in graphics and integrated circuits is closely tied in with the data systems research. A graphics program on TX-2 has been developed to facilitate greatly the design and layout of integrated circuits. The finished output, in the form of punched paper tape, is fed directly into a precision optical instrument that produces the tiny masks used for fabrication. Carrying the process one step further, computer techniques have been developed to carry out detailed electrical tests on the many complex circuits that are involved in large-scale integrated circuit applications.

The solid-state research program is concerned with materials with electronic, magnetic, or optical properties that may be of technological interest or importance. This year there have been a number of significant developments associated with infrared wavelengths in or near the 8-to-12 micrometer atmospheric window, where infrared energy can propagate through the atmosphere like visible light, without excessive attenuation. These promising practical developments are, of course, like the visible part of an iceberg, symbolic of the broader and more basic solid-state program from which they derive.

Extremely stable carbon-dioxide gas lasers operating at 10.6 micrometers have been developed, and CO₂ lasers have been used in a CW Doppler radar system for precise measurement of radial velocity. Alloys of lead-tin telluride and lead-tin selenide, in which the ratio of lead to tin determines the operating wavelength, have been widely and effectively exploited as photovoltaic detectors and as laser sources. Detectors with long-wavelength cutoffs as high as 30 μm have been produced. Detectors
made of copper-doped germanium have been operated at 10.6 μm with sensitivities near the theoretical limit.

A lead-tin telluride diode laser has been operated as a very stable, single-frequency local oscillator at 10.6 μm. By varying the current through this diode, the output frequency can be tuned continuously over a range of 50,000 MHz, rendering it a very promising device for infrared heterodyne detection techniques in many different applications. At somewhat shorter wavelengths in the 4 to 5 μm range, infrared images have been detected and converted to visible displays by scanning a uniform metal-oxide-semiconductor structure of indium antimonide with the beam of a helium-neon laser.

Our radio physics program, chiefly centered at Millstone Hill and the adjacent Haystack Facility, has had substantially increased participation this year by students and faculty from M.I.T. and Harvard, and collaboration with other radio and radar observatories throughout the world, notably with Cornell's Arecibo installation in Puerto Rico and with the National Radio Astronomy Observatory (NRAO) in West Virginia. Haystack played a key role in four-station, very long-baseline radio interferometer measurements, with the NRAO, the University of California, and Chalmers University of Technology in Sweden, which pinpointed at least eight tiny intense OH emission regions within a field of view comparable in size to a single stellar image on an optical plate.

The surface of the Haystack 120-foot reflector was readjusted to conform more precisely than ever to a paraboloidal contour; at 35 GHz, it now has a beamwidth of about one minute of arc, comparable to that of the human eye and believed to be the highest useful resolution yet achieved with a single antenna system. Versatile new techniques have been developed for digital recording, processing, and display of radio astronomy data, and a short film has been made to illustrate some of the procedures.

In radar astronomy, the most significant accomplishment was the validation of a new test of Einstein's theory of general relativity, which predicts gravitational retardation of an electromagnetic wave passing close to the sun. Radar returns from Mercury near superior conjunction were delayed, as predicted; the first preliminary results had an estimated accuracy of about 20 per cent, and considerably better accuracy is confidently expected from subsequent measurements.

Millstone, Haystack, and Arecibo data on Venus yielded a radius value significantly (35 km) smaller than that deduced from Venera 4 and Mariner 5 spacecraft data, strongly suggesting that the Venera 4 transmitter stopped before it reached the surface; this conclusion is inde-
pendently supported by other radar results. In mid-June, radar returns from the planetoid Icarus were obtained as it passed within about 4 million miles of the earth.

A systematic program of radar measurement of the ionosphere is continuing, and new exploratory programs to study the aurora, meteorological disturbances, and high-altitude layers of clear air turbulence have been initiated. In the latter case, an Air Force U-2 aircraft was used to correlate radar data with actual atmospheric conditions.

MILTON U. CLAUSER
Total operations of the Institute reached $214,000,000 in 1967-68 compared to $200,000,000 in 1966-67 and $178,000,000 in 1965-66. The 1967-68 increase in total operations was seven per cent compared with twelve per cent in the preceding year. The Sources of Revenues and Funds used to meet Expenses of Current Operations during the year on page 721 is a summary of the educational and general and sponsored research operations for 1967-68. The Balance Sheets on pages 719 and 720 illustrate the total financial and plant resources on June 30, 1968 of $418,000,000, an increase of ten per cent over the total resources of M.I.T. at the close of the 1967 fiscal year. An increase in the invested funds that make up sixty per cent of the total balance sheet assets was the source of half of the increase in resources in fiscal 1968. The statement on pages 722-723 of this report contrasts the funds at June 30, 1968, and June 30, 1967, illustrating the significant changes for the year.

OPERATIONS

As shown in the table below, the educational and general expenses of the Institute in 1967-68 increased twelve per cent compared with an increase of seventeen per cent in 1966-67. Departmental sponsored research expanded by ten per cent in contrast to eleven per cent in the previous year. The combined activities of the major laboratories increased three per cent as against ten per cent in 1967. The operations

1 The complete report of the Vice President and Treasurer, including schedules supporting those printed on the following pages; the list of gifts, grants, and bequests received during the year 1967-68; and reports of the Trustees of the M.I.T. Pension Association, Supplementary Retirement Plans and the Retirement Plan for Employees, is published separately and may be obtained on request from the Office of the Treasurer.
of the Instrumentation Laboratory were up nearly eleven per cent and the Lincoln Laboratory showed a small decrease in the volume of its activities in 1968.

<table>
<thead>
<tr>
<th></th>
<th>1967-68</th>
<th>1966-67</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational and general expenses</td>
<td>$54,652,000</td>
<td>$48,758,000</td>
</tr>
<tr>
<td>Direct expenses of general departmental and interdepartmental sponsored research</td>
<td>45,680,000</td>
<td>41,621,000</td>
</tr>
<tr>
<td>Direct expenses of major laboratories and special departmental research</td>
<td>106,678,000</td>
<td>103,793,000</td>
</tr>
</tbody>
</table>

The direct expenses of sponsored research are reimbursed by the sponsoring agencies, but the educational and general expenses represent the expenses undertaken within the projected revenues available to meet these charges.

Although new activities were important, the further increase in operations during the year was related largely to the continuing upward trend in salaries and wages and related benefits, with the total payroll of the Institute in 1967-68 amounting to nearly $100,000,000. Educational and general expenses reflect further growth in special programs including as examples basic research financed with funds from private sources, urban affairs, and an extension of computer services. General and administrative expenses increased substantially to provide further support services to the academic departments and laboratories. The larger plant operating expenses were identified with buildings constructed in recent years and now more fully utilized.

The direct expenses of the general departmental and interdepartmental sponsored research of $45,680,000 is for the most part closely associated and integrated with the activities included within the educational and general expenses. Although the direct expenses of sponsored research under the supervision of the academic departments is approximately forty-five per cent of the combined departmental research and educational and general expenses, only thirty per cent of the salaries and benefits of faculty members of professorial rank are financed by sponsored research revenues.

A major change in the financing of the Institute's educational and general operations has occurred since 1965 with the large-scale increase in student aid. In the condensed statement of educational and general revenues, student aid finances a large percentage of tuition and other income. Although student aid is granted for purposes other than tuition, total financial aid for students at M.I.T. has increased from twenty-five per cent of tuition income to nearly fifty per cent in the last ten years.
To illustrate this development further, total financial aid awards have been accelerated sharply since 1965 with the total of undergraduate aid in that year at $2,500,000 as compared with $3,800,000 in 1967-68, a fifty-two per cent change.

The following table illustrates the marked increase in undergraduate scholarships between 1965 and 1968, and the total increase in financial aid to undergraduates.

<table>
<thead>
<tr>
<th></th>
<th>1968</th>
<th>1965</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scholarships</td>
<td>$2,676,000</td>
<td>$1,407,000</td>
</tr>
<tr>
<td>Loans — M.I.T. resources</td>
<td>500,000</td>
<td>433,000</td>
</tr>
<tr>
<td>Loans — Government resources</td>
<td>588,000</td>
<td>697,000</td>
</tr>
<tr>
<td></td>
<td>$3,764,000</td>
<td>$2,537,000</td>
</tr>
</tbody>
</table>

The gifts, grants, and bequests in 1967-68 and 1966-67 were received as follows:

<table>
<thead>
<tr>
<th></th>
<th>1967-68</th>
<th>1966-67</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gifts for endowment</td>
<td>$6,619,000</td>
<td>$3,990,000</td>
</tr>
<tr>
<td>Gifts for buildings</td>
<td>2,641,000</td>
<td>4,095,000</td>
</tr>
<tr>
<td>Gifts for current use — invested</td>
<td>8,521,000</td>
<td>3,975,000</td>
</tr>
<tr>
<td>Industrial Liaison Program</td>
<td>1,255,000</td>
<td>1,400,000</td>
</tr>
<tr>
<td>Other funds for current use</td>
<td>3,111,000</td>
<td>2,559,000</td>
</tr>
<tr>
<td>Total gifts to funds</td>
<td>$22,147,000</td>
<td>$16,019,000</td>
</tr>
<tr>
<td>Grants-in-aid</td>
<td>3,734,000</td>
<td>1,843,000</td>
</tr>
<tr>
<td>Total</td>
<td>$25,881,000</td>
<td>$17,862,000</td>
</tr>
</tbody>
</table>

Private foundation support of special projects under the supervision of the academic departments was a major source of the grants included in the category of gifts for current use — invested. Bequests provided much of the increase in the total of new resources received by M.I.T. in 1967-68, with part of a substantial unrestricted legacy received during the year. Additions to the endowment were primarily designated for professorships, scholarships, and specific areas of research, along with the gift of an expendable fund classified as functioning as endowment.

Gifts for current use — invested, including some grants, are not necessarily included in income in the year received, but in the year they are used for operating expenses, and pending expenditure are for the most part invested and the investment income added to the fund.

The unrestricted direct gifts to the Alumni Fund of $751,000 are
included in the total of $2,875,000 credited by the Alumni Fund in 1967-68.

**FUNDS**

Total funds increased eight per cent during 1967-68, with endowment funds increasing by twelve per cent, other funds by nineteen per cent, and building and expendable funds decreasing by five per cent.

<table>
<thead>
<tr>
<th></th>
<th>1967-68</th>
<th>1966-67</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowment for general purposes</td>
<td>$61,932,000</td>
<td>$61,437,000</td>
</tr>
<tr>
<td>Endowment for designated purposes</td>
<td>73,237,000</td>
<td>59,441,000</td>
</tr>
<tr>
<td>Total endowment funds</td>
<td>$135,169,000</td>
<td>$120,878,000</td>
</tr>
<tr>
<td>Building and expendable funds</td>
<td>69,674,000</td>
<td>72,842,000</td>
</tr>
<tr>
<td>Other funds</td>
<td>55,039,000</td>
<td>46,182,000</td>
</tr>
<tr>
<td><strong>Total funds</strong></td>
<td>$259,882,000</td>
<td>$239,902,000</td>
</tr>
</tbody>
</table>

A large part of the increase in endowment for designated purposes was for the support of faculty salaries, and the addition of a fund transfer in part from expendable funds that in the future will function as endowment. Building and expendable funds representing resources available for future construction and operations decreased in 1967-68 but primarily because of the transfer to designated endowment. The income on designated endowment funds, and the restricted expendable gifts of new funds, while received in one fiscal year, are often expended over a period of years.

The increase in other funds was attributable primarily to net gains from the sale of investments during the twelve months ended June 30, 1968.

The investment income for distribution to funds was $9,800,000. The unallocated investment income was $6,645,000 on June 30, 1968. The general investments gain and loss account on the same date was $14,454,000, increased from $7,546,000 on June 30, 1967. Including the retirement funds, the total book value of the funds on June 30, 1968, was $341,592,000.

**PLANT FACILITIES**

The book value of the plant of the Institute on June 30, 1968 was $118,798,000, up from $107,871,000 on June 30, 1967. Buildings in the process of construction accounted for the greater plant value, and included the Center for Space Research, the Center for Advanced Engi-
neering Study, the Computer Building, the Chemistry Building, and the first phase of the central refrigeration facility. Some of the utilities required to service the growing plant of the Institute are financed from unrestricted gifts and grants and often require advance financing so as to be in place when new building requirements come on stream. The Institute has adopted the practice of allocating to the cost of funding new buildings most of the cost of the related new utilities and some part of the maintenance expense over a period of years.

In 1967-68 a loan agreement was initiated but not completed with the Department of Housing and Urban Development for a part of the cost of MacGregor House, with construction to be started in 1968.

At the end of the year, ten per cent of the book value of the plant was financed through loans from private and government sources. The advance from general cash resources of the Institute on a temporary basis for construction in progress was $2,725,000.

**INVESTMENTS**

The investments of the Institute on June 30, 1968 and June 30, 1967 are presented in the following table, which does not include the separately invested retirement funds under the supervision of the trustees of these funds.

<table>
<thead>
<tr>
<th></th>
<th>June 30, 1968</th>
<th>June 30, 1967</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Book Value</td>
<td>Market Value</td>
</tr>
<tr>
<td>General investments:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonds</td>
<td>$113,614,000</td>
<td>$103,622,000</td>
</tr>
<tr>
<td>Stocks</td>
<td>61,667,000</td>
<td>170,808,000</td>
</tr>
<tr>
<td>Real estate</td>
<td>20,977,000</td>
<td>20,977,000</td>
</tr>
<tr>
<td>Commercial paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certificates of deposit</td>
<td>152,000</td>
<td>152,000</td>
</tr>
<tr>
<td>Total</td>
<td>$196,410,000</td>
<td>$295,559,000</td>
</tr>
</tbody>
</table>

Special investments: $40,778,000 $49,915,000 $33,832,000 $42,788,000

Students' notes receivable: 9,270,000 9,270,000 8,251,000 8,251,000

Total: $246,458,000 $354,744,000 $232,151,000 $332,325,000

Funds sharing in the income from the general investments earned 6.7 per cent. Five per cent was allocated to the endowment funds plus an extra distribution of two per cent, in contrast to an extra distribution of one per cent in 1966-67. The income distribution to the other funds was
at the same rates and on the same basis as in 1966-67. Of the total investment income for the year, $6,865,000 was used directly for current expenses; $3,138,000 was added to balances of expendable funds, which in turn were used for current operating expenses to the extent of $3,376,000; and $2,164,000 was added to funds for scholarships, loans, and buildings.

The total investment income for the year on the general and separately invested funds was $13,502,000 compared with $12,788,000 in the preceding year, up more than five per cent. The income on the general investments has grown by over seventy per cent during the last five years, while the educational and general operations have shown an increase of more than sixty per cent over the same period. The rate of return on the general investments at original gift value before capital gains distributions has increased from 6.5 per cent in 1963 to 7.4 per cent in 1968.

The investments of the M.I.T. Pension Association, the Supplementary Retirement Plans, and the Retirement Plan for Employees on June 30, 1968, and June 30, 1967, are presented below:

<table>
<thead>
<tr>
<th>June 30, 1968</th>
<th>June 30, 1967</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book Value</td>
<td>Market Value</td>
</tr>
<tr>
<td>Pension Association</td>
<td>$36,041,000</td>
</tr>
<tr>
<td>Supplementary Retirement Plan — Fixed Benefit</td>
<td>18,775,000</td>
</tr>
<tr>
<td>Supplementary Retirement Plan — Variable Benefit</td>
<td>8,009,000</td>
</tr>
<tr>
<td>Retirement Plan for Employees</td>
<td>16,481,000</td>
</tr>
<tr>
<td>Total</td>
<td>$79,306,000</td>
</tr>
</tbody>
</table>

**GENERAL**

Common stocks at market continue at more than two-thirds of the endowment investments. Real estate investments are increasing, and investments have been undertaken to accommodate housing needs of the Institute community. Prospective long-term additions to academic plant are carried as real estate investments in the general portfolio.

JOSEPH J. SNYDER
**VICE PRESIDENT AND TREASURER**

**Schedule A: BALANCE SHEET, JUNE 30, 1968**

**CURRENT AND DEFERRED ASSETS**

<table>
<thead>
<tr>
<th>Description</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash:</td>
<td>$2,534,000</td>
</tr>
<tr>
<td>General purposes</td>
<td></td>
</tr>
<tr>
<td>Restricted, principally to research activities</td>
<td>7,702,000</td>
</tr>
<tr>
<td>Accounts receivable:</td>
<td></td>
</tr>
<tr>
<td>U. S. Government (A-14)</td>
<td>3,012,000</td>
</tr>
<tr>
<td>Other (A-14)</td>
<td>2,703,000</td>
</tr>
<tr>
<td>Contracts in progress, principally U. S. Government (A-15)</td>
<td>19,134,000</td>
</tr>
<tr>
<td>Inventories, deferred charges and other assets (A-16)</td>
<td>9,121,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$44,206,000</td>
</tr>
</tbody>
</table>

**INVESTMENTS**

General investments (at cost):

<table>
<thead>
<tr>
<th>Description</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. S. Government and agency bonds (A-14)</td>
<td>$39,270,000</td>
</tr>
<tr>
<td>Corporate bonds</td>
<td>70,630,000</td>
</tr>
<tr>
<td>Convertible bonds</td>
<td>3,714,000</td>
</tr>
<tr>
<td>Preferred stocks</td>
<td>346,000</td>
</tr>
<tr>
<td>Common stocks</td>
<td>61,321,000</td>
</tr>
<tr>
<td>Real estate (including $4,651,000 devoted to Institute use) and mortgages</td>
<td>20,977,000</td>
</tr>
<tr>
<td>Commercial paper</td>
<td></td>
</tr>
<tr>
<td>Certificates of deposits</td>
<td>152,000</td>
</tr>
<tr>
<td><em>(A-1)</em></td>
<td>$196,410,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investments of funds separately invested (A-2)</td>
<td>40,778,000</td>
</tr>
<tr>
<td>Students' notes receivable (A-13)</td>
<td>9,270,000</td>
</tr>
<tr>
<td><strong>Total investments</strong></td>
<td>$246,458,000</td>
</tr>
<tr>
<td>Cash held for investment</td>
<td>3,081,000</td>
</tr>
<tr>
<td>Receivables from sales of securities</td>
<td>3,902,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$253,441,000</td>
</tr>
</tbody>
</table>

*Total market, including real estate investments at cost, $345,474,000.

**EDUCATIONAL PLANT**

<table>
<thead>
<tr>
<th>Description</th>
<th>1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land, buildings, and equipment (A-20)</td>
<td>$118,799,000</td>
</tr>
<tr>
<td>Construction in progress</td>
<td>1,153,000</td>
</tr>
<tr>
<td>Temporary investment and cash</td>
<td>245,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$120,197,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$417,844,000</strong></td>
</tr>
</tbody>
</table>

719
### CURRENT LIABILITIES AND FUNDS

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounts payable</td>
<td>$10,558,000</td>
</tr>
<tr>
<td>Accrued wages and vacation allowances</td>
<td>$4,192,000</td>
</tr>
<tr>
<td>Withholdings, deposits, and other credits (A-17)</td>
<td>$1,820,000</td>
</tr>
<tr>
<td>Students' advance tuition, fees and deposits (A-18)</td>
<td>$1,753,000</td>
</tr>
<tr>
<td>Advances by the U.S. Government for certain research contracts and grants</td>
<td>$18,489,000</td>
</tr>
<tr>
<td>Unexpended grants for sponsored research from private sources</td>
<td>$3,678,000</td>
</tr>
<tr>
<td>Gifts and other receipts available for current expenses (A-19)</td>
<td>$6,441,000</td>
</tr>
<tr>
<td>Less funds advanced for educational plant (A-19)</td>
<td>(2,725,000)</td>
</tr>
<tr>
<td><strong>Total Current Liabilities and Funds</strong></td>
<td><strong>$44,206,000</strong></td>
</tr>
</tbody>
</table>

### INVESTED FUNDS

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowment funds:</td>
<td></td>
</tr>
<tr>
<td>Income for general purposes (A-3)</td>
<td>$61,932,000</td>
</tr>
<tr>
<td>Income for designated purposes (A-4)</td>
<td>$73,237,000</td>
</tr>
<tr>
<td><strong>Total Endowment Funds</strong></td>
<td>$135,169,000</td>
</tr>
<tr>
<td>Student loan funds (A-5)</td>
<td>$10,242,000</td>
</tr>
<tr>
<td>Building funds (A-6)</td>
<td>$6,764,000</td>
</tr>
<tr>
<td><strong>Total Expendable Funds</strong></td>
<td><strong>$152,175,000</strong></td>
</tr>
<tr>
<td>Other expendable funds:</td>
<td></td>
</tr>
<tr>
<td>General purposes (A-7)</td>
<td>$6,542,000</td>
</tr>
<tr>
<td>Designated purposes (A-8)</td>
<td>$56,368,000</td>
</tr>
<tr>
<td><strong>Total Other Expendable Funds</strong></td>
<td><strong>$62,910,000</strong></td>
</tr>
<tr>
<td>Unexpended endowment income for designated purposes (A-4)</td>
<td>$3,771,000</td>
</tr>
<tr>
<td>Agency funds (A-9)</td>
<td>$617,000</td>
</tr>
<tr>
<td>Funds subject to life interests in income (A-10)</td>
<td>$3,069,000</td>
</tr>
<tr>
<td>General investments — gain and loss account (A-11)</td>
<td>$14,454,000</td>
</tr>
<tr>
<td>Investment income for distribution to funds (A-12)</td>
<td>$9,800,000</td>
</tr>
<tr>
<td>Unallocated investment income (A-12)</td>
<td>$6,645,000</td>
</tr>
<tr>
<td><strong>Total Invested Funds</strong></td>
<td><strong>$253,441,000</strong></td>
</tr>
</tbody>
</table>

### EDUCATIONAL PLANT LIABILITIES AND FUNDS

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note payable to bank</td>
<td></td>
</tr>
<tr>
<td>Mortgage notes payable, 5¼% due 1968-1978</td>
<td>$973,000</td>
</tr>
<tr>
<td>Mortgage notes payable, 5¼% due 1968-1981</td>
<td>$978,000</td>
</tr>
<tr>
<td>Dining facilities bonds, 3½% due 1968-1999</td>
<td>$363,000</td>
</tr>
<tr>
<td>Married student housing mortgage bonds, 1961, 3½% due 1968-2001</td>
<td>$2,790,000</td>
</tr>
<tr>
<td>Student Center mortgage bonds, 1963, 3½% due 1968-2003</td>
<td>$2,920,000</td>
</tr>
<tr>
<td>Married students and married faculty housing mortgage bonds, 1965, 3¼% due 1968-2015</td>
<td>$4,000,000</td>
</tr>
<tr>
<td>Advanced from current funds</td>
<td>$2,725,000</td>
</tr>
<tr>
<td>Endowment for educational plant (A-21)</td>
<td>$105,448,000</td>
</tr>
<tr>
<td><strong>Total Educational Plant Liabilities and Funds</strong></td>
<td><strong>$120,197,000</strong></td>
</tr>
</tbody>
</table>

### Schedule A: BALANCE SHEET, JUNE 30, 1968

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Current Liabilities and Funds</strong></td>
<td><strong>$44,206,000</strong></td>
</tr>
<tr>
<td><strong>Total Invested Funds</strong></td>
<td><strong>$253,441,000</strong></td>
</tr>
<tr>
<td><strong>Total Educational Plant Liabilities and Funds</strong></td>
<td><strong>$120,197,000</strong></td>
</tr>
<tr>
<td><strong>Total Assets</strong></td>
<td><strong>$417,844,000</strong></td>
</tr>
</tbody>
</table>
VICE PRESIDENT AND TREASURER

Schedule B: SOURCES OF REVENUES AND FUNDS USED TO MEET EXPENSES OF CURRENT OPERATION
for the year ended June 30, 1968

EDUCATIONAL AND GENERAL

Expenses of current operation

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic departments</td>
<td>$24,131,000</td>
</tr>
<tr>
<td>General and administration</td>
<td>12,755,000</td>
</tr>
<tr>
<td>Student activities general and plant expenses and major dormitory repairs</td>
<td>1,788,000</td>
</tr>
<tr>
<td>Plant operation</td>
<td>10,444,000</td>
</tr>
<tr>
<td>Auxiliary activities</td>
<td>5,534,000</td>
</tr>
<tr>
<td>Total educational and general expenses</td>
<td>$54,652,000</td>
</tr>
</tbody>
</table>

Less contract allowances for general and administration, and plant operation expenses (see below) | 15,417,000 |

Sources of revenues and funds used

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition and other income</td>
<td>$15,723,000</td>
</tr>
<tr>
<td>Auxiliary activities</td>
<td>5,534,000</td>
</tr>
<tr>
<td>Total educational and general expenses</td>
<td>21,257,000</td>
</tr>
</tbody>
</table>

Sponsored research

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries and wages</td>
<td>$62,582,000</td>
</tr>
<tr>
<td>Pension and other employee benefit costs</td>
<td>7,706,000</td>
</tr>
<tr>
<td>Materials and services</td>
<td>49,515,000</td>
</tr>
<tr>
<td>Subcontracts</td>
<td>29,832,000</td>
</tr>
<tr>
<td>Travel</td>
<td>2,723,000</td>
</tr>
<tr>
<td>Research general and administration expenses</td>
<td>5,030,000</td>
</tr>
<tr>
<td>Allowances for general and administration, and plant operation expenses</td>
<td>15,417,000</td>
</tr>
<tr>
<td>Allowance for use of facilities and other reserves</td>
<td>1,603,000</td>
</tr>
<tr>
<td>Total sponsored research</td>
<td>$174,408,000</td>
</tr>
</tbody>
</table>

Revenues

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>General departmental and interdepartmental research</td>
<td>$55,199,000</td>
</tr>
<tr>
<td>Major laboratories and special departmental research:</td>
<td></td>
</tr>
<tr>
<td>Lincoln Laboratory</td>
<td>65,538,000</td>
</tr>
<tr>
<td>Instrumentation Laboratory</td>
<td>53,671,000</td>
</tr>
<tr>
<td>Total operations</td>
<td>$213,643,000</td>
</tr>
</tbody>
</table>

Total operations: $213,643,000
**Schedule C: STATEMENT OF FUNDS**

for the year ended June 30, 1968

<table>
<thead>
<tr>
<th>Description</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowment funds:</td>
<td></td>
</tr>
<tr>
<td>Income for general purposes</td>
<td>(A-3) $ 61,437,000</td>
</tr>
<tr>
<td>Income for designated purposes</td>
<td>(A-4) 59,440,000</td>
</tr>
<tr>
<td>Student loan funds</td>
<td>(A-5) 9,506,000</td>
</tr>
<tr>
<td>Building funds</td>
<td>(A-6) 7,891,000</td>
</tr>
<tr>
<td>Other expendable funds:</td>
<td></td>
</tr>
<tr>
<td>General purposes</td>
<td>(A-7) 3,880,000</td>
</tr>
<tr>
<td>Designated purposes</td>
<td>(A-8) 61,070,000</td>
</tr>
<tr>
<td>Unexpended endowment income for designated purposes</td>
<td>(A-4) 3,682,000</td>
</tr>
<tr>
<td>Agency funds</td>
<td>(A-9) 615,000</td>
</tr>
<tr>
<td>Funds subject to life interests in income</td>
<td>(A-10) 2,710,000</td>
</tr>
<tr>
<td>General investments — gain and loss account</td>
<td>(A-11) 7,546,000</td>
</tr>
<tr>
<td>Investment income for distribution to funds</td>
<td>(A-12) 9,500,000</td>
</tr>
<tr>
<td>Unallocated investment income</td>
<td>(A-12) 5,686,000</td>
</tr>
<tr>
<td>Total invested funds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$232,963,000</td>
</tr>
</tbody>
</table>

| Gifts and other receipts available for current expenses                    | (A-19) 6,939,000 |
|                                                                          | $239,902,000 |

<table>
<thead>
<tr>
<th>Description</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gifts received during the year added to funds</td>
<td></td>
</tr>
<tr>
<td>Royalties received net of related costs</td>
<td>698,000</td>
</tr>
<tr>
<td>Receipts from foundations and agencies for student aid</td>
<td>4,698,000</td>
</tr>
<tr>
<td>Net gain on sales or exchange of investments</td>
<td>9,221,000</td>
</tr>
<tr>
<td>Appropriations from research contract allowances</td>
<td>1,627,000</td>
</tr>
<tr>
<td>Government construction grants</td>
<td>2,028,000</td>
</tr>
<tr>
<td>Fees, services and other receipts</td>
<td>3,706,000</td>
</tr>
<tr>
<td></td>
<td>$44,125,000</td>
</tr>
</tbody>
</table>

| Endowment investment income used to meet expenses of current operation    |         |
| Gifts, investment income, and other receipts used to meet expenses of current operation |  

| Scholarship and fellowship awards for tuition and stipends                |         |
| Expenditures for buildings added to educational plant                     |         |
| Expenditures of service activities and other charges to funds not representing operating |  

*Investment income on endowment funds for designated purposes is included under the caption*
### Gifts and Other Receipts

<table>
<thead>
<tr>
<th>Gifts and Other Receipts</th>
<th>Investment Income</th>
<th>Transfers In-(Out)</th>
<th>Expenses</th>
<th>Other Charges</th>
<th>Balance June 30, 1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 443,000</td>
<td>$ 4,304,000</td>
<td>$ 21,000</td>
<td>$ 4,273,000</td>
<td></td>
<td>$ 61,932,000</td>
</tr>
<tr>
<td>8,477,000</td>
<td>$ 8,477,000</td>
<td></td>
<td></td>
<td></td>
<td>73,237,000</td>
</tr>
<tr>
<td>804,000</td>
<td>48,000</td>
<td>(70,000)</td>
<td>46,000</td>
<td></td>
<td>10,242,000</td>
</tr>
<tr>
<td>4,668,000</td>
<td>311,000</td>
<td>1,878,000</td>
<td>44,000</td>
<td>7,940,000</td>
<td>6,764,000</td>
</tr>
<tr>
<td>5,217,000</td>
<td>208,000</td>
<td>(2,213,000)</td>
<td>384,000</td>
<td>166,000</td>
<td>6,542,000</td>
</tr>
<tr>
<td>5,987,000</td>
<td>2,930,000</td>
<td>(7,128,000)</td>
<td>2,992,000</td>
<td>3,499,000</td>
<td>56,368,000</td>
</tr>
<tr>
<td>(6,634,000)</td>
<td>(397,000)</td>
<td>2,592,000</td>
<td>1,556,000</td>
<td>617,000</td>
<td>3,771,000</td>
</tr>
<tr>
<td>49,000</td>
<td>28,000</td>
<td>(49,000)</td>
<td></td>
<td>26,000</td>
<td></td>
</tr>
<tr>
<td>389,000</td>
<td>132,000</td>
<td>(44,000)</td>
<td></td>
<td>118,000</td>
<td>3,069,000</td>
</tr>
<tr>
<td>6,908,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14,454,000</td>
</tr>
<tr>
<td>(10,473,000)</td>
<td>10,773,000</td>
<td></td>
<td></td>
<td></td>
<td>9,800,000</td>
</tr>
<tr>
<td>352,000</td>
<td>11,380,000</td>
<td>(10,773,000)</td>
<td></td>
<td></td>
<td>6,645,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$33,294,000</td>
<td>$13,502,000</td>
<td>$(2,682,000)</td>
<td>$10,331,000</td>
<td>$13,305,000</td>
<td>$253,441,000</td>
</tr>
</tbody>
</table>

### Investment Income

<table>
<thead>
<tr>
<th>Investment Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4,304,000</td>
</tr>
<tr>
<td>8,477,000</td>
</tr>
<tr>
<td>$311,000</td>
</tr>
<tr>
<td>$208,000</td>
</tr>
<tr>
<td>2,930,000</td>
</tr>
<tr>
<td>(397,000)</td>
</tr>
<tr>
<td>28,000</td>
</tr>
<tr>
<td>132,000</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$4,304,000</td>
</tr>
<tr>
<td>8,477,000</td>
</tr>
<tr>
<td>$311,000</td>
</tr>
<tr>
<td>$208,000</td>
</tr>
<tr>
<td>2,930,000</td>
</tr>
<tr>
<td>(397,000)</td>
</tr>
<tr>
<td>28,000</td>
</tr>
<tr>
<td>132,000</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

### Transfers In-(Out)

<table>
<thead>
<tr>
<th>Transfers In-(Out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$21,000</td>
</tr>
<tr>
<td>(70,000)</td>
</tr>
<tr>
<td>1,878,000</td>
</tr>
<tr>
<td>(2,213,000)</td>
</tr>
<tr>
<td>(70,000)</td>
</tr>
<tr>
<td>(44,000)</td>
</tr>
<tr>
<td>(2,213,000)</td>
</tr>
<tr>
<td>(10,773,000)</td>
</tr>
<tr>
<td>(11,380,000)</td>
</tr>
<tr>
<td>$(2,682,000)</td>
</tr>
</tbody>
</table>

### Expenses

<table>
<thead>
<tr>
<th>Expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4,273,000</td>
</tr>
<tr>
<td>46,000</td>
</tr>
<tr>
<td>44,000</td>
</tr>
<tr>
<td>384,000</td>
</tr>
<tr>
<td>166,000</td>
</tr>
<tr>
<td>3,499,000</td>
</tr>
<tr>
<td>2,592,000</td>
</tr>
<tr>
<td>1,556,000</td>
</tr>
<tr>
<td>26,000</td>
</tr>
<tr>
<td>118,000</td>
</tr>
<tr>
<td>10,331,000</td>
</tr>
<tr>
<td>7,647,000</td>
</tr>
<tr>
<td>6,364,000</td>
</tr>
<tr>
<td>$17,978,000</td>
</tr>
<tr>
<td>$19,669,000</td>
</tr>
</tbody>
</table>

### Other Charges

<table>
<thead>
<tr>
<th>Other Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7,940,000</td>
</tr>
<tr>
<td>$6,364,000</td>
</tr>
<tr>
<td>$6,441,000</td>
</tr>
</tbody>
</table>

### Balance June 30, 1968

<table>
<thead>
<tr>
<th>Balance June 30, 1968</th>
</tr>
</thead>
<tbody>
<tr>
<td>$61,932,000</td>
</tr>
<tr>
<td>73,237,000</td>
</tr>
<tr>
<td>10,242,000</td>
</tr>
<tr>
<td>6,764,000</td>
</tr>
<tr>
<td>6,542,000</td>
</tr>
<tr>
<td>56,368,000</td>
</tr>
<tr>
<td>3,771,000</td>
</tr>
<tr>
<td>617,000</td>
</tr>
<tr>
<td>3,069,000</td>
</tr>
<tr>
<td>14,454,000</td>
</tr>
<tr>
<td>9,800,000</td>
</tr>
<tr>
<td>6,645,000</td>
</tr>
<tr>
<td>$253,441,000</td>
</tr>
</tbody>
</table>

Unexpended endowment income for designated purposes."
VICE PRESIDENT AND TREASURER

AUDITOR'S CERTIFICATE

TO THE AUDITING COMMITTEE OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY:

We have examined the financial statements of Massachusetts Institute of Technology:


Schedule B — Sources of Revenues and Funds Used to Meet Expenses of Current Operation for the Year Ended June 30, 1968.


Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. We used auditing procedures other than direct confirmation to establish the validity of certain U. S. Government receivables. We previously examined and reported upon the financial statements of Massachusetts Institute of Technology for the year ended June 30, 1967.

In our opinion, said statements present fairly the financial position of Massachusetts Institute of Technology at June 30, 1968, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a consistent basis.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts, September 5, 1968

REPORT OF THE AUDITING COMMITTEE

TO THE CORPORATION OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY:

The Auditing Committee reports that Lybrand, Ross Bros. & Montgomery were engaged to make an audit of the books and accounts of the Institute for the fiscal year ended June 30, 1968, and their certificate is submitted herewith.

Respectfully,

GILBERT M. RODDY
DAVID A. SHEPARD
ROBERT B. SEMPLE, Chairman
VICE PRESIDENT, OPERATIONS AND PERSONNEL

The gradual growth trend of recent years that has required new and expanded academic and research facilities and programs has caused a corresponding growth in services and support activities. As we add new buildings and upgrade old, there is a continual need to evaluate and review our operating systems and methods. Though the reports which follow underscore the tangible progress of the last year, there is a common undercurrent of analysis, planning, and activities which are the base, not of today's accomplishments, but of tomorrow's.

In the housing program, for example, two new residences were opened this year: McCormick Hall East for women, and the Eastgate married students' tower. Though these are the result of several years' efforts, of which we are justly pleased, they do not represent the end of the housing program. There remains an urgent need for new and improved student and staff housing. A considerable portion of the collective resources of the Physical Plant Department and the Housing Office is being applied to the solution of this problem, in stages during the next decade. Worthy of note is the granting of the contract for MacGregor House, the first of several hoped-for new undergraduate residences for men.

Recounting the year's major construction activity is impressive because a number of new facilities were completed and placed in operation. Four new academic and research facilities were opened in addition to the two new residences. They were the Center for Advanced Visual Studies, the Center for Space Research, the Center for Advanced Engineering Study.
and the Information Processing Services Center. A new Central Refrigeration Plant was placed in operation to provide efficient and economical air conditioning of the new facilities. Obviously, these are the result of many years of planning, design, and construction. Their completion does not indicate a slackening of the pace, as we are now working on the requirements of the future.

Although much of our effort looks ahead, some resources are being applied to our immediate environment. A casual tour of the campus shows the results of a stepped-up landscaping program. This program not only has added new planting areas near buildings, but has added several gardens to enhance the atmosphere and alleviate the urban starkness.

Another improvement to the environment, long in the planning stage, is now ready for construction. The Cambridge City Council recently approved plans for the improvement of Massachusetts Avenue from Memorial Drive to Vassar Street. The work, including new traffic control procedures, pedestrian crossings, and landscaping, will improve the safety and appearance of this busy section of the campus.

Problems caused by the tight Boston labor market continue to be a challenge in the area of personnel recruitment. This problem extends over virtually all categories of employment and is expected to continue in the months ahead. We continue to make special efforts to encourage employment applications from members of disadvantaged groups and are working with 45 local agencies specializing in this area of employee recruitment. Last summer's Summer Youth Employment Program was well received by the M.I.T. community and has been continued this year. The program's goal is not just to provide a few jobs, but to provide a meaningful work experience to a disadvantaged young person who would not ordinarily get this opportunity.

Though employment levels rose at about the same modest rate as last year, losses due to accident and injury showed an encouraging decrease. Efforts will continue to be directed toward increased surveillance and education in the area of safety and loss prevention.

The past year, with all its achievements and accomplishments, did not pass without some loss. Mrs. Gertrude B. Winquist, who served as Director of Endicott House since its start in 1955, left M.I.T. for a position with the Ford Foundation. This spring she was lost to all of us through death. All those who have had the opportunity to use Endicott House will long remember her contributions to the M.I.T. community.

PHILIP A. STODDARD
EMPLOYMENT
Total non-academic employment at the Institute, including the Lincoln Laboratory and the Instrumentation Laboratory, increased about 2.2 per cent during the past year, at approximately the same rate as the year before. However, the rate of increase on the campus declined significantly from 6.7 per cent the previous year to 4.0 per cent this year.

Termination rates continued to increase and there was difficulty in recruiting replacements in virtually all categories employed by the Institute. Despite this fact, a total of approximately 1,650 individuals joined the Institute’s non-academic staff during the year. Special efforts were made to encourage employment applications from members of disadvantaged groups. These efforts included special advertising and recruiting, liaison with 45 local agencies which specialize in preparing and placing the disadvantaged, and helping in programs such as the Summer Youth Employment Program. The Institute is a member of Plans for Progress, the Equal Employment Opportunities Commission, and the Massachusetts Plan for Equal Employment Opportunity.

TUITION ASSISTANCE
Participation in the Tuition Assistance Plan for Employees and the Tuition Plan for staff continued to be high during the past year. Almost three-fourths of those studying under the Tuition Plan for Employees were enrolled in degree programs, with Northeastern University by far the most popular evening school. Under the plan for staff, a total of 409 staff members received $61,457 as tuition reimbursement; $44,355 of this amount was reimbursement for subjects taken at the Institute. Under both plans the maximum reimbursement for evening study at other schools was raised from $300 per year to $400.

UNION RELATIONS
Two-year agreements with three unions representing about 2,500 Institute employees were due to expire on July 1, 1968. Negotiations have been in progress since the middle of May. Agreement was reached on June 29, 1968, with the Building Service Employees’ International Union representing maintenance and custodial employees at the Lincoln Laboratory on the terms of a new two-year agreement. The new agreement provides for increases of $1.50 per cent each year, and in addition, the Institute agreed to absorb the anticipated increase in the cost of hospitalization and medical insurance coverage during this period. Negotiations with the other unions are continuing.
VICE PRESIDENT, OPERATIONS AND PERSONNEL

COMPENSATION PROGRAMS
General salary structures were analyzed during the year and adjustments made as necessary to maintain appropriate alignment with applicable local and national patterns. In addition, the wages and salaries of more than 6,000 employees were reviewed by their supervisors, and individual adjustments were made on a merit basis within the prescribed framework. Vacation policies for virtually all non-academic personnel were improved during the year to keep pace with changes made by other employers in the area.

The coverage of the staff vacation, life insurance, and extended disability plans were extended to supervisory and other exempt personnel, separating for the first time the benefit coverage of those key personnel from that of the "non-exempt" personnel.

CAMPUS PATROL
The function of the Campus Patrol is to help, in any way it can, students, faculty, and employees within the limits of its obligations to the Institute community as a whole, to maintain an orderly campus, and to cooperate with the City of Cambridge in its effort to provide an orderly community. Problems faced by the Campus Patrol have increased in complexity, number, and size much more rapidly than the growth of the community itself. For example, in 1962 there were a total of 325 written complaints submitted to the Campus Patrol Office; in 1967 there were 740, an increase of 127 per cent for the five-year period. In just the last two years, 1966 and 1967, ambulance service provided by Campus Patrol jumped from 225 to 395 cases, an increase of 78 per cent, and parking violations rose from 6,000 to 9,125, up 52 per cent. During the past year on-campus thefts have risen sharply, following a national trend in this direction. Situations involving missing or disturbed persons have also shown a sharp increase. In fact, the Institute faces all of the problems of misdemeanors, crime, accidents, disturbed persons, traffic control, and parking that face any normal city or town of 15,000 persons. It is becoming a major challenge to continue to provide for the safety, well-being and convenience of our growing community in the manner which the community demands.

ROBERT J. DAVIS

PHYSICAL PLANT
The last year was a year of new building occupancy in the Institute's building program. More than 500,000 gross square feet of new floor area was occupied, including the Eastgate Apartment Tower, the Center
PHYSICAL PLANT

for Advanced Visual Studies, the Center for Space Research, the Center for Advanced Engineering Study, McCormick Hall East, and the Information Processing Services Center. The Central Refrigeration Plant was completed and is operating at about 50 per cent of initial capacity, supplying chilled water for air conditioning to the Center for Advanced Engineering Study, the Center for Space Research, the Information Processing Services Center, and the Center for Theoretical Physics in the Eastman Building.

CONSTRUCTION

During the year, work continued on the Chemistry Graduate Research Building, which is now scheduled for completion in 1969. New projects for which construction was initiated during the year are:

ENGINEERING LIBRARY REHABILITATION AND RENOVATION – INTREX

This project involves the complete remodeling and renovation of the Engineering Library. This was constructed as the Central Library in 1916 and converted to an Engineering Library in 1952. The original cast-iron stacks are being removed and replaced with library facilities consistent with the latest information retrieval concepts developed under Project INTREX. The general character of the dome will be retained as a feature of the up-dated facility.

LINEAR ACCELERATOR

A joint effort by the Atomic Energy Commission and the Institute, the 400-million electron volt Linear Accelerator, is being built in Middleton, Massachusetts, to be operated by the Laboratory for Nuclear Science. Scheduled for completion in 1970, the project includes a 600-foot beam path tunnel, 650-foot radio frequency gallery at ground surface, target area, and supporting office and control building.

MAC GREGOR HALL

Construction is scheduled to start in July on a new 324-student men's dormitory facing Memorial Drive just west of Burton-Conner. This facility will have a reinforced concrete framed 16-story tower faced with brick and linked with a five-story low-rise brick section. The facility will include a dining commons, master's house, tutors' suites, enclosed courtyard area, and recreation facilities.

HYDRODYNAMICS ADDITION

Construction is also scheduled to start in July on a two-story addition to the existing Hydrodynamics Building constructed in 1949 on Vassar
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Street. The addition will house offices, laboratories and classrooms, and will include an elevator-stair tower at the west end of the building. Air conditioning will be provided for both the new and existing spaces.

 MASSACHUSETTS AVENUE CROSSING

The first phase of a traffic and pedestrian control project was started along Massachusetts Avenue, involving traffic lights and pavement marking at the main entrance. Design work continued on revised sidewalks, curbs, planting, street furniture, lighting and fencing, intended to redefine the street and channel pedestrians and vehicles in a safe and efficient manner.

 LANDSCAPING

As new construction work is completed in a particular part of the campus, the contiguous ground areas are being improved by the addition of plants and other landscaping. During the year landscaping was done between Ashdown House and McCormick Hall East, around the Bush Building, and along Ames Street. Thinning the sycamore grove near the chapel provided street trees for the front of McCormick East and the Bush Building. The Julie Fassett Memorial Garden at the approaches of the west campus housing area was substantially completed in June.

 MAJOR ALTERATION, REMODELING AND UTILITIES EXPANSION PROJECTS

Major space renovations and alterations and utility expansion projects with an aggregate value of about two million dollars were completed during the year. About 100,000 square feet of floor area was involved in this program. In many cases it was necessary to upgrade and augment basic electric, plumbing and ventilation facilities in order to meet prevailing standards of building services. Outstanding renovations were made at the Center for Theoretical Physics on the third and fourth floors of the Eastman Building. This was an experiment in recasting the main corridor arrangement to provide congenial dialogue spaces surrounded by clusters of offices. Initial reaction from the new occupants has been very favorable. Preliminary studies are in process for renovating space to be vacated by the Department of Chemistry when the new Chemistry Graduate Research Building is completed in 1969. The first phase of this effort was completed this year with the upgrading of portions of the mechanical systems of the large undergraduate chemistry laboratory. Design work is also progressing on a west campus utilities expansion project that initially will provide electric, telephone, and steam service for the new MacGregor Hall and subsequently take care of future west campus expansion south of the railroad right of way.

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PHYSICAL PLANT

PROPOSED CONSTRUCTION
During the year preliminary design work was initiated for a new Electrical Engineering Communications Research Facility on a site along Vassar Street just east of the new Information Processing Services Center building. This facility is intended to house substantial portions of the Department of Electrical Engineering and the Research Laboratory of Electronics. Site selection studies were made for an enclosed, year-round tennis facility on the west campus.

OPERATIONS
In addition to the many problems of occupying new facilities, the operating group of the Physical Plant Department has continued to work for operational improvements both in organization and systems. During the year, the new positions of Superintendent of Grounds and Superintendent of Building Maintenance were filled, and other necessary personnel changes were made.

A study of power factor correction led to the decision to install power factor correction equipment at the Instrumentation Laboratory facility at 75 Cambridge Parkway, resulting in gains in increased substation capacity and lower unit cost of purchased power. Power factor correction is also under way for that portion of Institute electric power supplied by the Cambridge Electric Light Company through our three main substations. Purchased power for the year through these three substations increased by about 11 per cent over the previous 12 months.

Another Physical Plant area showing tremendous growth is the provision of heating, ventilating, and air conditioning services. The quantity of air conditioning in both new and existing buildings has increased from 1,000 tons in 1958 to 12,000 tons in 1968. Support personnel in the mechanical service group have increased proportionately. Use of data processing for planned maintenance scheduling and follow-up is continuing. A training program for mechanical service personnel, organized in conjunction with a similar group at Harvard University, has completed its second year. This program, attended by 40 M.I.T. mechanics, was initiated in order to fill a gap in the technical training programs available in the Greater Boston area.

One of the new features installed during the year is a two-way radio system primarily for use in dispatching building maintenance vehicles. This system, with its aerial on the top of the Eastgate tower, is also proving to be a valuable aid in providing rapid intracampus communications during Institute functions and emergencies.

Looking forward, the Institute faces several problems in the expan-
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sion and continuing operation of its physical plant. The effects of unusually high local construction cost increases during the past 12 months have been evident in recent bidding, and all indicators point to pyramid- ing cost escalation in the next several years. This calls for very careful project management to maximize returns on capital investment and to avoid costly design and construction delays due to receipt of bids in excess of estimates. Operating costs are expected to rise more steeply due both to higher labor and material costs and the greater concentration of mechanical services in new and renovated facilities.

The policy of regular budgeting for planned maintenance will have to be continued on a larger and more organized scale to provide adequately for systematic renewal of Institute facilities that have almost doubled in floor area in the last 15 years.

CARL M. F. PETERSON

SAFETY OFFICE

Accident injury and severity ratios are slightly lower than they were last year, and the loss rate indicates a substantial decrease in comparison with last year's figures.

The program to eliminate architectural barriers continues to move ahead with considerable progress, evidenced by the number of ramps and dropped curbs at both new and old buildings, facilitating movement by the physically handicapped. The Institute felt it had made sufficient progress in this area to act as host for the Bay State wheelchair games in June.

Installation of automatic sprinkler systems and fire detection devices continues in Institute buildings, with emphasis placed on dormitories.

J. David Hobbs resigned to accept a position in industry as of June 1, 1968.

MARK J. DONDERO

HOUSING AND DINING SERVICES

HOUSING

The urgent demand for improved and expanded undergraduate and graduate housing facilities is discussed by the Dean of Student Affairs. Although this housing shortage will continue until major construction and
HousinG and dining services

Renovation programs are completed, two new residential towers were completed for occupancy this year. The Eastgate married student/faculty apartments, completed and fully occupied in October, provide one- and two-bedroom apartments for 148 student families and 49 faculty members. Additional facilities include six apartments for guests of the Institute, a number of lounges for community use, and a store and nursery school.

The east tower of McCormick Hall was completed and occupied in February, 1968. This provides accommodations for 105 additional undergraduate women, bringing the total projected dormitory occupancy to 221 beds. The rooms are grouped in suites, and a number of lounges and recreational facilities are included in the building.

To provide housing for all freshmen, a rooming house was renovated and occupied in February by 100 undergraduate men. It is anticipated that the facility must be used until new undergraduate housing is completed, at which time it will revert to Northgate Community Corporation, the owner.

In June a contract was awarded for the construction of MacGregor House, a new dormitory housing 324 undergraduate men. Occupancy is anticipated in late spring, 1970.

During the last year, Lucille Leverone, Administrative Assistant, left the housing office after 18 years of generous service to countless M.I.T. students seeking her advice on housing matters. We are grateful for her untiring efforts during her tenure at M.I.T.

This year the housing and dining operations have been strengthened by the central accounting office assuming responsibility for accounting procedures. A substantial review of present accounting practices is in progress.

In August, David K. Cantley was appointed general manager of the M.I.T. Dining Service. Largely through his leadership, the financial position of the Dining Service has improved significantly, due in part to some service curtailments designed to have a minimal impact on the student community. This year, Salvatore Lauricella assumed responsibility for the Student Center dining services, and was presented the first James N. Murphy Award, awarded to an employee of M.I.T. whose spirit and loyalty exemplify the service of Mr. Murphy, especially with regard to students.

In addition to other activities, the Dining Service this year undertook the responsibility for catering the Alumni Day and Commencement occasions. It was a gratifying conclusion to the year's work.

Laurence H. Bishoff
VICE PRESIDENT, OPERATIONS AND PERSONNEL

GRAPHIC ARTS SERVICE

The past year has seen innovation in manufacturers' pricing and equipment which has allowed the Graphic Arts Service to increase its printing volume and efficiency well over that attributable to normal growth. The savings realized by these new techniques have been passed on to the M.I.T. community through better quality, service, or lower prices. The most outstanding example of this effect is seen in our Xerox printing service which, as a result of a price reduction in January, had a 50 per cent increase in volume for the year. New high-speed duplicating equipment is being tested which we are certain will make copies of improved quality in less time and will allow further reduction in prices.

In our offset printing department we are replacing our older and slower equipment with the latest type of web presses as well as new plate making and bindery equipment. By the time the new academic year begins in 1968, we are certain that we will be in a position to offer quicker service, better quality, and lower prices than ever before. This past year our offset printing plant produced more than 65 million impressions.

The Bulk Mail division continued to grow at a rate of approximately 25 per cent this past year, representing the handling of more than one million pieces of mail. The balance of our services, which include photography, letter shop, and illustration, have had an active year and growth has been normal.

The Audio-Visual Service expanded its operation into new quarters in the basement of Building 4, enabling it to offer more services with additional equipment and personnel. An indication of the demands being brought upon Audio-Visual are reflected in the fact that in 1964 there were four employees and by 1968 this figure has increased to 11 employees.

FRANK H. CONANT

ENDICOTT HOUSE

Endicott House suffered a double loss this year. Mrs. Gertrude B. Winquist, the Director and guiding spirit of M.I.T.'s conference center since it started in 1955, left Endicott House November 1, 1967, to assume a position at the Ford Foundation. She has been succeeded at Endicott House by Mrs. Elim O'Shaughnessy. It was later learned that Mrs. Winquist died suddenly in May, 1968.
ENDICOTT HOUSE

Endicott House was open nine months in 1967-68 and closed July, August, and January. The house was used 217 days, including 161 nights by resident groups. Overnights totaled 3,953, an average of about 24 guests a night for resident conferences. A total of 63 non-resident groups used the house during the year. While the house was open, 14,777 meals were served, or an average of 68 meals a day.

Endicott House was fortunate this year to receive part of the furnishings willed by Mrs. Stanley McCormick to M.I.T., which has added to the attractiveness and comfort of the house.

MARY O'SHAUGHNESSY
The problem of summarizing a full year’s activity is ordinarily difficult, given the range of administrative functions reporting to the President through the Vice President and Secretary of the Institute. In an extraordinary year, such as 1967-68, the problem is compounded by sheer volume. The level of activity reached by the Corporation and its committees, the development program, and the Institute’s relationships with industry combined to produce one of the busiest years of late. Added to this heavier-than-usual cycle of meetings, visits, reports, and events was a record number of formal observances related to the Institute’s building program and two important academic ceremonies, for which the Office of the Vice President and Secretary provided administrative support. It was a year electrified by widespread national attention given to student unrest on the nation’s campuses, deep concern for Federal support of higher education, especially Federal funding of university research, and growing discussion of the problem of financing the private colleges and universities. All of these factors made 1967-68 a standout year among the annual milestones at M.I.T.

CORPORATION
At the year’s end there were 79 Members of the Corporation, 66 Active Members and 13 Life Members Emeriti. During the year Irenée duPont Jr. ’43, Vice President and Director of E. I. du Pont de Nemours & Co., Inc., was elected a Life Member. Frank R. Milliken ’34, President, Kennecott Copper Corporation; Thornton A. Wilson ’53, President, The Boeing Company; William E. Hartmann ’38, General Partner, Skidmore, Owings & Merrill; Henry E. Singleton ’40, Chairman and Chief Executive Officer, Teledyne, Inc.; and Gregory Smith ’30, President
and General Manager, Eastman Gelatine Corporation, were elected Term Members of the Corporation — all for five-year terms. Our Life Member, Cecil H. Green '23, was elected President of the Alumni Association for 1968-69, and will succeed Gregory Smith on July 1, 1968.

Expiration of Term Membership has cost the Corporation the formal associations of Louis W. Cabot, President, Cabot Corporation, Elisha Gray II '28, Chairman, Whirlpool Corporation; Thomas F. Morrow '35, Group Vice President, Chrysler Corporation; and William L. Taggart '27, President, Dewey and Almy Chemical Division, W. R. Grace & Company.

As a matter of record, the Corporation met formally in four regular quarterly sessions, and on a number of occasions during the year the Corporation was host at ceremonies marking the formal opening of major laboratories and the dedication of other new facilities at the Institute.

In a noteworthy action the Corporation moved to appoint an Ad Hoc Committee on the Structure of the Corporation. This Committee, under the chairmanship of our Life Member, Marshall B. Dalton, was continuing its deliberations at year's end. Individual Members of the Corporation added to an impressive record of service to M.I.T. by their participation in numerous national committees, panels, and boards. The nature of these public service activities by the Corporation gives a measure of the national stature of the individuals involved.

CORPORATION VISITING COMMITTEES

The Visiting Committees of the Corporation, operating as advisory groups to the Corporation, continued to bring invaluable information and stimulus to the educational and research programs of the Institute. This vital communications system included 219 individuals serving on 26 committees — 50 members nominated by the Corporation, 90 members nominated by the President, and 79 members nominated by the Alumni Association. In total, 247 committee positions were filled by these groups, the Corporation Members serving generally on two or more Standing or Visiting Committees of the Institute's governing body. As in the past, the presidential and alumni nominees were distinguished scientists, engineers, educators, and businessmen joined with the Corporation Members in the work of these Committees. The 26 Visiting Committees were chaired by Members of the Corporation who made oral and written reports on their principal findings. Twenty-four of the 26 Visiting Committees held meetings at M.I.T. with the following departments:
This level of activity represented a substantial increase over the nine Visiting Committee meetings held last year and was due, in part, to the previous year's lower frequency of meetings. The bunching of three-fourths of these meetings in the second academic term emphasized once again the need for improved spacing throughout the year and the importance of seeking a more even pattern of meetings from year to year. Roughly 18 meetings a year is a desirable norm—some Committee chairmen and academic departments preferring an annual meeting, others preferring to meet less frequently. An over-all attendance record of 80 per cent in the Committee meetings held this year gives one measure of the interest shown by Committee members in serving the Institute.

An important factor in the success of this advisory system has been the thoughtful preparation for the meetings by department heads and the consistent participation of the deans and senior officers of the Institute in the meetings. Special thanks are due Dr. Jerome B. Wiesner, Provost, for his strong support of the Visiting Committees and for his wise counsel in the selection of new Committee Members for the coming year.

This year, as part of a continuing effort to provide improved administrative support to the Visiting Committees, a new picture booklet on the composition of the Committees was published for the first time.

At midyear, Paul E. Johnson joined the Office of the Vice President and Secretary of the Institute, replacing Walter L. Koltun in the pro-
VICE PRESIDENT AND SECRETARY

vision of scheduling and information services to Visiting Committee members and to department chairmen. Mr. Johnson, formerly Assistant Director of Admissions, brings sound experience in academic administration to the Visiting Committees. In addition, he has skillfully carried out the planning and execution of dedicatory activities. A partial listing of programs for which this office had primary or partial responsibility follows: Center for Theoretical Physics, Center for Advanced Visual Studies, Center for Space Research, McCormick Hall East, Eastgate Residence Tower, Naming of the Francis Bitter National Magnet Laboratory, Groundbreaking for MacGregor Hall, Woods Hole Oceanographic Institution – M.I.T. Ceremony, and Commencement Exercises.

RELATIONS WITH INDUSTRY

The Industrial Liaison Office completed its 20th year of operation, continuing as it has throughout two decades to emphasize the interests and activities of individual members of the Faculty as the basis for the industrial Liaison Program services.

Inaugurated in September, 1948, the Program has served as a model for similar programs of collaboration with industry at some 50 American colleges and universities. Virtually all of the institutes of technology and the leading universities that maintain strong schools of science, engineering, and management have established programs of scientific liaison with industry, based on M.I.T.'s experience. The Program continues to receive national and international attention as an outstanding example of what a university can do to organize improved communication with industry. During a period of unprecedented growth and change at M.I.T., it has contributed substantially to the professional development of the Faculty and of the Institute. The unrestricted revenues it has brought to M.I.T. have played a critical role in maintaining M.I.T.'s independence and strength as a privately controlled educational institution.

It is fitting that this historical commentary on the Industrial Liaison Program include a tribute to Dr. James R. Killian, Jr., who conceived the Program as a result of discussions with the late Egar V. Murphree, President of Esso Research and Engineering Company, about ways and means through which major corporations might increase their support of higher education appropriately. It is no accident of history that the great growth of corporate aid-to-education, which began in the late 1940's and early 1950's, coincided with this development at M.I.T. Four M.I.T. faculty members were instrumental in shaping the Program to the Institute's needs and imparting to it a fundamental concern for
the responsibilities and protection of faculty members. They were Dr. Julius A. Stratton, then Provost, Dean C. Richard Soderberg of the School of Engineering, and Professors Antoine M. Gaudin and Warren K. Lewis; the latter two served as early faculty consultants to the Program. A fifth faculty member, Professor Walter H. Gale, was its principal representative in the first ten years of the Program. The Institute owes a lasting debt to the wisdom and foresight of these M.I.T. faculty members. I am confident that this recognition does not reflect invidiously on the generous participation of other faculty members, too numerous to mention by name, who have contributed unselfishly to the success of the Industrial Liaison Program over the years.

The reports of the directors of the Industrial Liaison Office and the M.I.T. Associates Office follow in a later section.

DEVELOPMENT

In November, 1967, President Johnson announced a 1967-1975 projection of $135 million in capital resources needed by the Institute, over and above annual gifts and grants earmarked for operating purposes. In his announcement President Johnson called for an annual level of $30 million in gifts, grants and bequests from private sources in order to meet M.I.T.'s over-all capital and operating needs.

In addition to this $135 million capital projection, President Johnson set a goal for the immediate enlargement of the Institute's total invested funds from $332 million to $500 million.

This announcement, presented in the context of the President's Report to the Corporation, began a new era in planning for the acquisition of major resources for the Institute. For the first time the Institute publicly announced a comprehensive capital projection — not in the context of a capital fund drive, but in the context of an annual summary of capital needs which would be updated annually to take account of the Institute's changing priorities.

Foremost among the capital needs identified by President Johnson's announcement are $14 million to construct new facilities for the Department of Electrical Engineering and the Research Laboratory of Electronics, $14 million for faculty development, additional funds to construct a second undergraduate residence following MacGregor House, additional scholarship endowment, funds to support innovation in education, and support for the libraries.

During the year the special appeal for electrical engineering and electronics facilities was launched with the endorsement of the Corporation
Visiting Committee for the Department of Electrical Engineering, the Corporation Development Committee, the Corporation itself, and a special Faculty Advisory Committee on the project. In support of this project, applications for Federal construction funds were submitted to the National Science Foundation, the National Institutes of Health, and the U.S. Office of Education. Nelson C. Lees prepared a comprehensive statement to support the Institute’s appeal to private donors. By year’s end the funds secured stood at just over $4 million of the $14 million needed. John H. Carter, Institute Secretary, has served as project officer on this drive, along with special studies he has made of venture capital methods of securing private contributions.

The Institute made notable progress during the year towards its goal of increasing the total of endowed and named professorships. Kenneth J. Germeshausen ’31 made a magnificent gift of $600,000 to establish The Germeshausen Professorship, an Institute-wide chair to foster teaching and research in interdisciplinary fields at M.I.T. John W. Gardner, Chairman of The Urban Coalition, was appointed first Visiting Germeshausen Professor. Included in a $3 million urban affairs program grant by the Ford Foundation are funds for three permanent faculty chairs at $600,000 each.

In another noteworthy action, friends and alumni of Course X came together to launch a drive for $600,000 to establish an endowed professorship honoring Dr. Warren K. Lewis. A committee under the chairmanship of Crawford H. Greenewalt ’22 is leading this effort. At year’s end roughly half of the endowment had been pledged or contributed. David J. Tobin, Institute Secretary for Charitable Trusts, is serving as project officer on this drive.

Shortly after the President’s announcement of the Institute’s $135 million capital projection, a second announcement was made, of an increase in tuition from $1,900 to $2,150 per two-term year, beginning with the fall of 1968. The latter announcement, brought on by the necessity to provide relief to the Institute’s operating budget, made all the more urgent the redoubling of our efforts to secure greater scholarship resources.

Beyond the total of capital projects identified by President Johnson, a greater number than usual of requests for advice and assistance in the funding of departmental projects from private sources came from individual faculty members. This increased demand reflected a general tightening of Federal funds available for university research, a shift of faculty interest into a number of new fields for which well-established support does not presently exist (notably urban programs), and a
greater awareness among faculty members of the Institute's desire to coordinate private appeals for funds.

Five years ago, at the conclusion of the Second Century Fund, the Institute set a new course in its drive to stay free and strong. In place of the short-term, highly publicized capital campaign, M.I.T. chose to begin a continuous search for capital resources against a changing annual projection of capital requirements over the ensuing decade. This approach was considered to be more in keeping with modern methods of capital budgeting and more consistent with sound business practice in the older, better established functions of university administration.

It may be too early to conclude that this new approach is superior, but there can be no doubt that it works. In the aggregate, M.I.T. has received more private support than any other college or university, save Harvard, during the past five years. The cash flow of gifts, grants, and bequests from all private sources during the past five years has totaled more than $130 million. This five-year total for 1963-1968 compares with nearly $80 million received in the previous five years, 1958-1963; it represents more than one-third of all cash gifts, grants, and bequests given to M.I.T. since its founding 107 years ago. Interestingly, the $130 million total includes more than $100 million beyond the payment of Second Century Fund pledges, which are now virtually completed.

Five years may also be too soon to tell whether this pattern of fund raising is adequate to the task. While the above totals are impressive, they include gifts given for both capital and operating purposes, and it remains true that M.I.T.'s unfulfilled capital needs are greater today than ever before. Likewise, operating funds and unrestricted monies are at an historical premium. The whole scale of need and opportunity has risen sharply, and this aspect of M.I.T.'s financial posture is the heart of a communication problem which the Institute has yet to resolve satisfactorily. At the same time, it is interesting to note that other leading, privately supported universities in recent years have adopted a similar plan for their long-range development.

Operationally, it is not easy to cope with the natural lumpiness of capital budgeting, but a few universities, M.I.T. among them, have made an important start in this direction. What these institutions have lost in terms of a publicized sense of urgency associated with the intensive, high-pressure campaign, they have more than gained in the steady buildup of their own managerial effectiveness, credibility, long-term relationships with major private donors, and the improved planning that goes hand in hand with a continuous, high-level development process.
One is tempted to speculate that the continuous, unrelenting growth and change that characterizes contemporary universities would have brought about a corresponding change in their search for private capital, regardless of collegial preferences.

As their ability to plan more effectively has grown, it has also weakened their earlier reliance on intermittent capital drives. These often have been invested publicly with a drive for improvement and academic excellence, but for the most part they have been attempts to catch up with a combination of prior growth and change, and the crushing effects of inflation in capital replacement costs. All too often they have been the product of an inability or unwillingness of university administrations to plan.

During the past year three documents appeared which have bared the facts nationally concerning the financing of higher education. One of these, which promptly became something of a best seller, was written by Dr. Killian and entitled, "Don't Sell Our Private Colleges Short!" It sought to dispel a growing wave of pessimism about the survival power of the private institutions and to warn against alarming trends in Federal support of university research.

In the spring of 1968, the Association of American Universities published "The Federal Financing of Higher Education," which made a strong appeal for greater Federal support; and the American Alumni Council joined with the Council for Financial Aid to Education for the first time in publishing a joint survey of private support—a continuation annually—which presents a greatly improved summary of the role of philanthropy in American higher education.

All of these reports, and a fourth entitled, "Graduate Education and Basic Research," by the Committee for the Support of American Universities, represented milestones in the broad national buildup of concern over the financial crisis facing American higher education. One of the important effects of the mounting concern was to focus the attention of the current Carnegie Commission on Higher Education almost exclusively on the number one problem, student unrest notwithstanding, confronting American colleges and universities—money.

All of these studies reflect common views of the over-all inadequacy of private and Federal support for the nation's colleges. The greatest threat to the national strength of higher education is that it has not yet been given the national priority it warrants. The greatest threat to the quality of our leadership institutions is clearly that the private sector continues to take them largely for granted.

In the steady buildup of development activity at M.I.T., it is a
pleasure to report that the search for new sources of funds has continued under the guidance and stimulus of the Corporation Development Committee. The expansion of the Committee in 1965 to include 100 distinguished alumni has continued through the past three years. Further strength was added to the Committee in 1967-1968 so that at year's end there were 117 members serving in this Standing Committee of the Corporation, including 13 Corporation Members. One reflection of heightened activity resulting from the work of the Committee was an increase in the number of off-campus solicitation visits by the development staff; these grew by 50 per cent during fiscal year 1967-1968.

Another important area of growth was the Estate Gift Program, under the able direction of D. Hugh Darden. The number of estate plans on record with the Institute stood at 634 at year's end. This compares with 566 estate plans on record a year ago, and it is nearly triple the number reported three years ago. The confidential nature of these plans and the sheer volume of detail involved in working out satisfactory estate gift arrangements with donors on an individual basis have required special efforts to supervise the orderly growth of this crucial area of development. The experience gained to date points up markedly the need for more supervision and the closest possible coordination of the work of the Class Estate Secretaries — the cadre of volunteer alumni workers on whom the Institute must depend for advice and assistance in promulgating sound policies and procedures for estate gift solicitation among alumni broadly. To meet these growing needs, Arnold H. Singal was appointed Staff Associate in the office of the Institute Estate Secretary at year's end. I join Mr. Darden in welcoming him and in expressing appreciation to the Office of the Vice President and Treasurer and to the Alumni Association for the invaluable assistance and cooperation which have been given to the Estate Gift Program during the past year.

C. Warren Smalzel continued as Institute Secretary for Corporations during the year. The completion of the drive to fund the new Chemistry Building and the start of funding operations on the Electrical Engineering and Electronics Complex, both of which are based heavily upon corporate grants, have been the principal focus of corporate solicitation in 1967-1968. A number of companies have elected to respond to M.I.T.'s request for assistance in these projects through their participation in the Industrial Liaison Program or the M.I.T. Associates Program. Mr. Smalzel also provided strong support to the departments and laboratories in communicating with corporations and their foundations broadly regarding gifts and grants for departmental purposes. As
in the past, corporate sources accounted for a substantial fraction of
unrestricted funds made available to M.I.T. by private donors. At no
time in the Institute’s modern era have these funds played a more im-
portant role.

In total, more than 400 companies made contributions to M.I.T.
during the year, not including those that made alumni matching gifts. There were 1,603 separate corporate gifts. Roughly one-fourth of the
corporations making grants either increased or decreased their level of
support, the gains approximating the losses to M.I.T.

David J. Tobin continued as Institute Secretary for Charitable Trusts,
and Paul H. Burr was appointed Institute Secretary for Foundations at
midyear, replacing Walter L. Koltun, who resigned to accept a position
in industry. These competent and experienced foundation officers to-
gether provided excellent staff support to a wide range of M.I.T.
projects and programs seeking foundation support. In total, 83 founda-
tions and charitable trusts made 146 grants amounting to $11,616,836,
including 16 foundations that made grants to M.I.T. for the first time.
The latter figure is significant, for it gives one measure of the extent to
which the Institute is making progress in its search for new sources of
funds and its efforts to broaden its base of foundation support.

Finally, the undersigned reports with a profound sense of loss the
departure of Joseph J. Lambert, Director of the Development Office,
who resigned to accept a similar post at Tufts University. He is suc-
cceeded by Nelson C. Lees, former Assistant Director of the Development
Office. During the nearly seven years he served in the Development
Office, Mr. Lambert made a major contribution to the Institute’s de-
velopment effectiveness, and he will be missed sorely.

In other staff changes, Jack W. Christensen succeeded Frank T.
Bauchspies as Director of the Industrial Liaison Office at the beginning
of the year; David H. Robbins succeeded Tom Yonker as Director of
the M.I.T. Associates Office. Both of the retiring directors have accepted
positions in industry. The reports of the new directors follow.

VINCENT A. FULMER

INDUSTRIAL LIAISON OFFICE
This is the 20th year of operation of M.I.T.’s Industrial Liaison Pro-
gram. In addition to recapping the past year’s accomplishments as we
approach the completion of our second decade, it is appropriate to
pause and reflect upon the Program’s activities and purpose.
Originally conceived as an organization to facilitate the exchange of information between faculty and representatives of industry, the Industrial Liaison Office continues to find that concept adequate as a guide for its activities. Although the goals may have served unchanged over the years, the methods employed to achieve them have evolved steadily to the point where we now offer a multiplicity of routine and personalized services to the member companies of the Industrial Liaison Program. These services include publications, symposia, personal visits with the faculty and research staff, and the day-by-day attention of professionally trained liaison officers intimately acquainted with the Institute's research programs and sensitive to the individual interests of the companies which they represent. Later sections of this report will present statistics reflecting an impressive volume of activity between the M.I.T. community and industry conducted under the auspices of the Industrial Liaison Program, but the nature of our "business," information exchange, makes it impossible to record or measure fully the total impact of those events either on the Institute, or on the firms with which this close association has been established.

Without question the Industrial Liaison Program has brought significant benefits to the Institute. It has served as a focal point for contact between our faculty and their counterparts within those firms that comprise the heart of American industry. Often, the Liaison Office is only involved in the initial phases of what later develops into long-standing, direct personal associations between individuals. While not a formal function of the Industrial Liaison Program, by its very nature this interface with industry, maintained by the Liaison Office, has exerted positive influences upon other facets of the M.I.T. environment, including the academic and research programs, sponsored research, and private consulting.

Participation in the Industrial Liaison Program has proven a worthwhile investment for our sponsoring firms as well. The routine services which their membership makes available, principal among which are the symposia and publications, provide an approach for the easy access of information concerning the Institute's extensive research. The more specialized range of services, involving personal visits with members of the Faculty and the full-time availability of the Liaison Office staff, enable representatives of the supporting companies to interact with the resources available at M.I.T. at any appropriate level. Moreover, the Liaison Officer assigned to the individual company as its representative on campus takes an active role in assuring that the company is kept informed of progress in areas of technology being explored here in
which they have a particular interest. The value of the Program to industry is further attested by the record of renewed memberships — 33 of the present member companies supporting the Industrial Liaison Program have been continuous participants for the last 15 years. Some 60 companies have now reached their tenth year.

A true perspective of the Liaison Program must also credit the Institute’s Faculty, without whose support these accomplishments could not have been realized. Their voluntary participation in symposia programs and the time they devote to discussions with industrial representatives at the request of the Industrial Liaison Office provide the personal interaction which is the life stream of the Liaison Program. I want to acknowledge again the important contributions of the Faculty to our activities and to reaffirm our determination to make efficient use of their efforts and to conduct the Program at a high professional level.

At the close of the fiscal year, there were 103 companies participating in the Liaison Program. The distribution of these companies among major industrial groups was as follows:

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace</td>
<td>20%</td>
</tr>
<tr>
<td>Automotive</td>
<td>4%</td>
</tr>
<tr>
<td>Chemical</td>
<td>16%</td>
</tr>
<tr>
<td>Electronics</td>
<td>21%</td>
</tr>
<tr>
<td>Food</td>
<td>3%</td>
</tr>
<tr>
<td>Insurance</td>
<td>2%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>11%</td>
</tr>
<tr>
<td>Metals</td>
<td>9%</td>
</tr>
<tr>
<td>Paper</td>
<td>1%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>9%</td>
</tr>
<tr>
<td>Others</td>
<td>4%</td>
</tr>
</tbody>
</table>

A record attendance of 2,299 was established during the Industrial Liaison Symposia series. A total of 18 individual meetings were offered (one less than in the prior year), as a means of providing timely, in-depth reports on those of the Institute’s research programs of special import to the companies. Responding to those programs were 1,751 representatives of companies participating in the Program, an increase of 22 per cent over the previous year; the remaining attendance was accounted for by representatives of the M.I.T. community and by special guests, including sponsors of the research being reported. One hundred forty-three of the Institute’s faculty and staff presented the results of their research and exchanged ideas with the audience during these meetings. Topics span the range of M.I.T.’s research activities and are selected on the basis of their application to industrial use and the amount of new, often previously unreported, information available for presentation. Two of the past year’s symposia dealt with topics of relevance.
to the aerospace industry and were held in Los Angeles as a convenience to the large number of supporting companies whose operations center in that area.


Attendance alone is not taken as the measure of a meeting's value to the participants, and our goal remains to use the symposia as a forum for the presentation of fresh information emanating from areas of active research at M.I.T. in an atmosphere which promotes the examination and discussion of those ideas among the faculty and attending industrial representatives. Whether involving research, engineering, management or other fields, the symposia are designed to be useful to those key individuals working at the forefront of their professions. However, high attendance does indicate areas of special concern to companies and we were not surprised to register 485 people at the recent "Management of Research and Development" symposium. The previous record attendance for a single symposium was 405.

Personal contact between faculty and representatives of the member companies for the purpose of discussing areas of mutual concern of either a long-range nature or of immediate application is one of the most significant features of Industrial Liaison Program services. These visits arise in a number of ways: They may come about as a result of the company's review of technical reports on various projects under way at the Institute and its wish for further up-to-the-minute information on those studies, or to explore the specific applications of that work to the company's own research and engineering activities. They may come about as a direct request on the part of the company either to talk with a specific faculty member or to explore a subject area. They often arise out of the individual liaison officer's initiative in bringing people together to discuss activities of mutual interest. During the past year 308 campus visits were arranged through the Industrial Liaison Office. A total of 351 faculty and staff took part in discussions with company repre-
sentatives during 624 separate appointments. A total of 458 key individuals represented 86 member companies during those meetings.

The Industrial Liaison Office also encourages members of the Faculty to visit company research laboratories. Companies welcome this chance to acquaint the faculty with their research programs and for the opportunity the visits provide for personal, on-scene discussions with their technical staffs. Typically, these visitations involve a seminar and informal discussions, and enable the faculty representatives to review, firsthand, those of the company's R&D programs that relate to their own areas of specialization. Participating faculty find it useful to contrast their own research with that of industrial firms and report enthusiastically on the value they receive from the professional contact thus achieved. A total of 88 visits by faculty members to member companies under the auspices of the Industrial Liaison Office were recorded during the year.

Each year the Industrial Liaison Office compiles the Directory of Current Research, a complete listing of research under way at M.I.T. The 1968 edition of the Directory contained a record listing of 1,487 projects. It serves as a ready reference not only to the companies but to the faculty as well, and furnishes a convenient means of attaining access to those activities. More than 2,600 copies of the Directory were distributed directly to participating companies this year. In addition, 1,250 copies were provided to the faculty and staff, and an additional 554 copies were personally distributed to company representatives by the industrial liaison officers. Beyond remaining informed on the current status of each project, the Liaison Office maintains and continually updates a file of publications generated by each project.

Selectively, in accord with the specific interests expressed by various divisions and laboratories of each company, the Liaison Publications Office automatically forwards copies of the Institute's technical reports. During the year more than 175,000 documents, representing 372 separate preprints and laboratory reports, were distributed to 524 different company locations. An additional 337 other reports were made available upon request. Copies of the Monthly List of Publications were sent regularly to 922 key individuals (who do not receive the automatic distribution), and that service resulted in further requests for Institute publications. Separate requests of this nature which were processed during the year totaled 4,690; an increase of 20 per cent for that service. The increasing use of this particular activity by the companies can be attributed to the special effort which has been devoted by the Office to
M.I.T. ASSOCIATES PROGRAM

bringing the Institute's publications to the attention of industry and to developing a system that makes their acquisition convenient.

Many of the companies have found it worthwhile to provide the Liaison Office with copies of technical reports generated within their research facilities. Seven hundred fifty-four reports of this type were received during the year, most of which could be forwarded directly to the faculty member having a special interest in their content. Physical access to the M.I.T. library system is provided by library privilege cards issued to representatives of member companies of the Industrial Liaison Program. This service, provided without charge in cooperation with the M.I.T. Libraries, makes it possible to use the Institute's facilities and to borrow documents consistent with usual library regulations. At the close of this year 607 library privilege cards were held by representatives of member companies.

Enthusiasm, imagination, and dedication are prerequisites for the industrial liaison officers and the importance of their role in fulfilling our commitments to the supporting companies cannot be overstated. Already having received the satisfactions inherent in the accomplishments reported above, they also deserve to share in the credit. During the year Arthur J. Collias, Peter B. Franz, Karl B. Kehler, Carl H. Neu, Ronald S. Stone, George W. Ullrich and the undersigned served as industrial liaison officers. At the year's end, Peter C. Farrell was appointed to the staff, replacing Mr. Franz, who has accepted a position in industry. Last May, after five years of service as a member of the Industrial Liaison Office staff, and its Director for the last two years, Frank T. Bauchspies accepted the challenge of a career in industry. In assuming responsibility for the direction of the Office, I readily accept the obligation to carry forward, and build upon, the strong Program which he helped establish.

JACK W. CHRISTENSEN

M.I.T. ASSOCIATES PROGRAM

Since its inception in 1961, the M.I.T. Associates Program has increased its participating membership steadily, and it has expanded in scope and diversity the important liaison functions which are the charter of this office. At year's end there were 27 participants in the Program. The long-range objectives of the Program are (1) to provide its industrial membership with broad opportunities for working relationships with the Faculty and staff of the Institute; (2) to give formal recognition to those
organizations which, through their continued interest in and support of the Institute, value highly their associations with M.I.T.; and (3) to communicate current information on selected educational and research activities of special importance to each of the members. These purposes are implemented through the personal representation of each company's particular interests on campus.

One example of the broadening scope of the Program is the industrial classification of its two newest members. Genesco, a diversified apparel manufacturer and distributor, is a leader in its field in applying the latest technological achievements to one of the oldest industries. The New England Merchants National Bank represents a first from the banking field to join the membership of the Associates Program.

A major function of the Associates Office is to inform the member companies of activities and new developments in their respective fields of interest. An "Agenda of Selected Activities" is distributed monthly, as well as the "Institute Calendar," "Reports on Research," selected press releases, special meeting and colloquia notices, and other material relating to current events at the Institute. In addition to these, selected progress reports, technical papers, preprints, and special periodicals such as *Technology Review* and the *Industrial Management Review* are forwarded on a regular basis. During the past year more than 1,100 such reports were selected and distributed to the membership.

Another significant sector of activity is that of individual consultations with the faculty. A total of 51 visits in the format of discussions, seminars, and luncheon meetings were arranged on topics such as air pollution control, electromechanical machining, advanced time-sharing applications, management information systems, utility control systems, and mass spectrometric applications. It is worthy of note that a wide variety of purposes were involved in these visitations, ranging from the exchange of professional notes to the initiation of student projects, a point that clearly illustrates the two-way benefits of such personal confrontations between the faculty and industry. Furthermore, eight companies arranged for consultants to aid them in solving key problems, and one company was given special assistance in the recruitment of a Director of Research as a result of contacts made through the Associates Office.

This year 125 company officers attended the Special Conference for New England Executives. Topics discussed at this conference on Radio and Radar Astronomy included the newly discovered hydroxyl radical, quasars, astronomical space probes, illustrations of radar astronomy, and the major engineering problems in the design and construction of the 120-foot parabolic Haystack antenna. At a dinner Dr. Peter C. Gold-
DEVELOPMENT OFFICE

mark, Director of the C.B.S. Laboratories, described new engineering breakthroughs in videotape equipment which will have significant impact on educational television. Many of those attending the conference visited the Lincoln Laboratory's Millstone Hill Complex the following day and saw firsthand the Haystack radar telescope facility.

In closing, I would like to take this opportunity to express appreciation on behalf of the member companies as well as the Associates Office to the Faculty and staff of the Institute, whose cooperation and interest have made possible another successful and stimulating year.

DAVID H. ROBBINS

DEVELOPMENT OFFICE

The cash flow of private gifts, grants, and bequests to M.I.T. for fiscal 1967-1968 totaled $25,881,026.37. It represented the second largest gift income total in the history of the Institute, and exceeded the previous year's total by $8,019,447.01 or approximately 45 per cent. Included in this year's total were payments on Second Century Fund pledges amounting to $1,513,690.45.

M.I.T.'s sources of private gift support were the following in the amounts specified:

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumni and Alumni Clubs</td>
<td>$ 8,325,491.85</td>
</tr>
<tr>
<td>Non-Alumni Friends</td>
<td>1,134,390.82</td>
</tr>
<tr>
<td>Corporations, Corporate Foundations</td>
<td>4,783,055.97</td>
</tr>
<tr>
<td>and Trade Associations</td>
<td></td>
</tr>
<tr>
<td>Foundations and Charitable Trusts</td>
<td>11,616,835.62</td>
</tr>
<tr>
<td>Others</td>
<td>21,252.11</td>
</tr>
</tbody>
</table>

Among the major purposes for which gifts were designated by the donors in both endowed and expendable funds were the following:

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted</td>
<td>$ 8,009,036.83</td>
</tr>
<tr>
<td>Departmental</td>
<td>9,689,675.03</td>
</tr>
<tr>
<td>Faculty salaries</td>
<td>2,803,858.13</td>
</tr>
<tr>
<td>Graduate scholarships and fellowships</td>
<td>879,110.52</td>
</tr>
<tr>
<td>Undergraduate scholarships, awards and loan funds</td>
<td>944,796.52</td>
</tr>
<tr>
<td>Building construction funds</td>
<td>3,321,698.39</td>
</tr>
<tr>
<td>Other funds</td>
<td>232,850.94</td>
</tr>
</tbody>
</table>
Again this year, the Institute's development program emphasized core needs of M.I.T. and found a favorable response among benefactors for programs of faculty development, student aid, and general unrestricted giving. In recent months an important effort has been under way to endow a professorial chair in honor of Dr. Warren K. Lewis, and this program has been most favorably received among the several audiences concerned with the Department of Chemical Engineering and with the profession generally. A further addition to the continuing program to build faculty strength was the generous gift of Mr. and Mrs. Kenneth J. Germeshausen to endow the Germeshausen Chair at M.I.T. It was also the Institute's privilege to learn this past year of the munificent bequest of Mrs. K. Dexter McCormick, which will assist M.I.T. greatly as her benefactions are received in subsequent years.

In the area of capital projects, a major effort has been under way, and is continuing, to secure $14 million to develop a new Electrical Engineering and Electronics Complex. This program represents the largest single fund-raising project in the history of the Institute.

At this time, I want to take the opportunity to express, both personally and on behalf of the Development Office, my very deep appreciation to the many members of the Institute's Faculty and administrative staff who have cooperated so fully in furthering the interests of the Institute during my eight years with the Development Office. In leaving, I wish them well and all success in their important efforts. I know that my successor, Nelson Lees, will be greatly strengthened and assisted in his efforts by their staunch support and enthusiastic spirit.

JOSEPH J. LAMBERT

REGISTRY OF GUESTS
The Registry completed its first year in its handsome new quarters, adjacent to the main entrance of the Institute. The convenience of this location has been of tremendous assistance in providing for visitors a pleasant welcome, a very comfortable waiting room, and easy access to M.I.T.

It is interesting to note that while there were fewer short-term foreign visitors during the year ending June 30, 1968, than in recent years, by contrast there were more long-term foreign faculty and staff in residence than ever before.

Just under 700 short-term visitors from 74 countries were programmed at M.I.T. this past year. Japan provided the greatest number of visitors (100), while the Sloan School of Management and the Depart-
ment of Civil Engineering were hosts to the largest numbers of foreign visitors. The figures cited above do not include the many foreign guests who attended conferences at the Institute or presented lectures under the auspices of various M.I.T. departments and laboratories.

A total of 476 foreign staff and faculty were appointed to the Institute as of November 15, 1967, and the increase over the previous year was evenly divided between teaching and research, as evidenced in the following tabulation:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Guests</td>
<td>28</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Administration</td>
<td>—</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Teaching</td>
<td>24</td>
<td>125</td>
<td>143</td>
</tr>
<tr>
<td>Research</td>
<td>131</td>
<td>297</td>
<td>315</td>
</tr>
<tr>
<td>Total</td>
<td>183</td>
<td>441</td>
<td>476</td>
</tr>
</tbody>
</table>

The largest proportion of foreign staff came from England (60), with 52 countries represented in all.

The Registry continued to work closely with the Committee on Commencement. In addition this Office secured delegates, principally from among the Alumni, to represent M.I.T. at academic functions throughout the world.
The office of Vice President, Organization Systems is new at M.I.T., having been established in August, 1967. Its purpose as defined in the announcement of its formation is to "... provide staff support to the President, the Provost and the Deans, and other Institute officers, in the conduct of studies to improve our administrative organization; to develop more effective internal information and communication flows; to coordinate organization planning; to support and advance the physical planning effort of the Institute; and to assist in evaluating our internal processes — all with the goal of improving the Institute's administrative system for our faculty and students."

To give organizational effect to these responsibilities, the M.I.T. Planning Office and the Office of Institutional Studies were associated with the office of the Vice President, Organization Systems. The reports of those two offices follow and in large measure reflect the scope and concerns of my office as well.

The central issues to which our efforts have largely been directed over the past year are two: the further refinement of a long-term physical development plan for the Institute and the integration of our information systems for planning and administration.

The goal of our long-term planning effort is to give written expression to the objectives of the Institute and to decisions about its rates of growth and directions of development. That our plan will be changed is inevitable, even essential, for the pace of change in our society is such that no one can foresee the demands on the Institute or its opportunities over the next dozen years. Nevertheless, a plan, regularly amended under the pressure of events, is important as a guide to coordinated action by the Institute community. To be effective, a plan must contain assumptions
and reflect decisions about the extent and areas of growth throughout the Institute. It must examine the pressures on our physical resources — land, laboratories, classrooms, libraries, offices, housing, athletic and community facilities, parking areas, even grass and trees. It must propose means of accommodating these pressures through land acquisition, construction, renovation and relocation. Finally, it must estimate the costs, both capital and operating, of carrying out this plan of growth and change, and the probable sources of revenue.

On all these questions, M.I.T. has consistently looked ahead and sought to map future needs and the means to meet them. The refinement we plan now is to push the planning horizon still further ahead, to coordinate all these separate elements into a single framework so that, given the interacting systems character of the Institute, the effects of decisions in one area on the whole can be evaluated. The particular role of the Vice President, Organization Systems, and the Planning Office is to provide the framework in which the decisions made by those with the responsibility can be translated into a coordinated plan. Our goal is to have the first formulation under this approach ready for review and discussion by the beginning of the 1968-69 academic year.

The second major focus of attention has been on the potential for integrating our information systems for planning and administration. This means, essentially, the conversion to computer of our major systems for handling information — on financial resources, on individuals, on the physical spaces of the Institute, and linking these systems together so that the information in the various files can be related. In certain administrative areas, notably the accounting and budgetary process and the student application, aid, and record processes, M.I.T. has been in the vanguard of universities adapting the computer to its administrative needs. Over the past year, we have been examining the potential gains in moving strongly ahead in other areas now and in ensuring compatibility among the systems through common definitions, codes, and computer linkages. By its very nature, the effort to achieve a measure of integration implies coordination of the work of many individuals. The primary vehicle for this review has been a study committee representing the principal users and the principal processors of information and, more recently, a senior committee to give policy direction and review progress. This latter committee will concern itself, as well, with the allied questions of the nature of the information required for various administrative decisions and the organizational level to which it should go. I am hopeful that next year's report will be able to record substantial additional progress in this area.

These two tasks have been the principal effort of the office over the past
The balance of time has been devoted to a number of special studies in support of decisions with organizational and resource implications and to two other events which were not my substantive responsibility but which my office assisted in organizing.

One of these was the visit to M.I.T. of a Re-evaluation Committee, formed by the New England Association of Colleges and Secondary Schools, to review M.I.T.'s accreditation. The rules of the Association require such a review every ten years. Only M.I.T. and a handful of other "complex and well-established institutions" in New England remained to be visited this year. A committee of eight faculty members and administrators of other colleges and universities led by Dr. Edwin Young, President of the University of Maine, spent March 31 and April 1 and 2 at the Institute. The formal report has not yet been received from the Association, but the visit effectively served the purposes of such a review in the fruits of our own preparatory self-examination and discussions with the Committee.

The second event was the decision to create a joint M.I.T.-Harvard non-profit corporation, the University Information Technology Corporation. The objective of the Corporation is to expand collaboration between the two institutions in sharing educational and research resources through the developing technology of information transfer. Illustrative of possible activities of the Corporation are the development of a closed-circuit television system between Harvard and M.I.T. for transmission of lectures and special events, sharing of computational facilities, and electronic transfer of information between the two library systems. Trustees of the Corporation will be the presidents and certain other senior officers of Harvard and M.I.T. The Executive Director will be Dr. Carl F. J. Overhage, M.I.T. Professor of Engineering and presently director of the experimental library program, Project INTREX.

I wish to take the occasion of this first report to express my appreciation to the staffs of the M.I.T. Planning Office and the Office of Institutional Studies, on whom I have leaned heavily during this year of education into a new set of responsibilities and particularly to the effective leadership of O. Robert Simha and Dean L. Jacoby, respectively, directors of those two offices.

JOHN M. WYNNE

OFFICE OF INSTITUTIONAL STUDIES

THE BASIC ROLE OF THE OFFICE

During the 1968 fiscal year the Office of Institutional Studies continued to provide administrative data processing services to 14 existing and
to eight new client offices: the Faculty Committee on Admissions and Student Aid, the Development Office, the Division of Sponsored Research, the Medical Department, the Purchasing Office, the Student Personnel Office, *The Tech*, and the Vice President, Operations and Personnel. A complete list of the client offices is included with this report with a brief description of the nature of the project assignment.

Additionally, computer time was provided for three M.I.T. offices without systems development support to meet unusual demands which exceeded their own computer capability.

Since the Office endeavors to tailor its services to meet the requirements of its client offices, the nature of individual projects varies substantially. Typically, existing administrative information systems are

<table>
<thead>
<tr>
<th>Client Office</th>
<th>General Nature of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions Office</td>
<td>Broad-scale file and output systems</td>
</tr>
<tr>
<td>Alumni Office</td>
<td>Broad-scale file and output system</td>
</tr>
<tr>
<td>*Faculty Committee on Admissions and Student Aid</td>
<td>Special studies</td>
</tr>
<tr>
<td>*Development Office</td>
<td>Deferred gifts historical file</td>
</tr>
<tr>
<td>*Division of Sponsored Research</td>
<td>Computer time and operating system only</td>
</tr>
<tr>
<td>Educational Council</td>
<td>Broad-scale file and output system</td>
</tr>
<tr>
<td>Department of Mathematics</td>
<td>Academic class lists</td>
</tr>
<tr>
<td>*Medical Department</td>
<td>Systems feasibility study</td>
</tr>
<tr>
<td>Department of Nuclear Engineering</td>
<td>Mailing lists</td>
</tr>
<tr>
<td>Physical Plant</td>
<td>Computer time and operating system only</td>
</tr>
<tr>
<td>Placement Office</td>
<td>Job application listing</td>
</tr>
<tr>
<td>Planning Office</td>
<td>Computer time and operating system only</td>
</tr>
<tr>
<td>*Purchasing Office</td>
<td>Typewriter and dictating machine file</td>
</tr>
<tr>
<td>Registrar</td>
<td>Broad-scale file and output system</td>
</tr>
<tr>
<td>Dean of Student Affairs and Freshman Advisory Council</td>
<td>Entering student information from General Student File</td>
</tr>
<tr>
<td>Student Aid Center</td>
<td>Broad-scale file and output system</td>
</tr>
<tr>
<td>Student Personnel</td>
<td>Student earnings analysis</td>
</tr>
<tr>
<td>Summer Session Office</td>
<td>Prospective registrant mailing lists</td>
</tr>
<tr>
<td>*The Tech</td>
<td>Advertising billing system</td>
</tr>
<tr>
<td>Undergraduate Planning Professor</td>
<td>Special studies</td>
</tr>
<tr>
<td>*Vice President, Operations and Personnel</td>
<td>Computer time and operating system only</td>
</tr>
</tbody>
</table>

maintained on a continuing basis by the Office of Institutional Studies, including specifically the commitment to provide outputs on a continuing production basis according to calendar schedules. The Office operates a leased IBM 360-30 computer for this purpose and purchases time from the M.I.T. Computation Center for large-scale computer requirements.

The responsibility of the Office in the development of new systems normally includes the definition of the systems requirements, specific systems design and computer programming. Such development is carried out in close coordination and under the direction of the client office, but the service provided is such that the client office need not employ on its staff a competent computer specialist.

1968 NOTEWORTHY DEVELOPMENTS

Beyond this continuing basic commitment, 1968 saw further development within the Office in two important areas:

1. Request for information systems assistance has been received from a much broader segment of the total Institute organization than in the past; thus the role of the Office as the primary service agency in this area seems to be tacitly understood.

2. During the year the suitability of the Institute’s approach to information systems for administrative and management purposes has been under review, and this Office has been asked to play a substantial role in that process.

In this regard, it now seems clear that whether or not an integrated information system is formally established at M.I.T., there will be greater concern in the future that the individual information systems avoid overlapping and ambiguous data. The Office of Institutional Studies will insure that the interface of new systems with those already existing will be thoroughly reviewed by all concerned offices.

INTERNAL OPERATIONS CONTROL

During the year all of the work of the Office was formally categorized by project number for each client office, with personnel and computer time as incurred being recorded in a computerized billing system. It is the Office’s objective to reflect the cost of information systems in the initiating office’s budget, so that control of this major cost element can be more easily effected. A partial charging system was in effect for the current year and it will be extended to include all client offices without exception in the coming fiscal year.
Development work on new systems has been delineated in three stages, reflecting the desirability of having formal check points at which the client office reviews the extent of the system under development and makes the decision to proceed to the next level. This replaced a more informal approach which did not require specific decisions as the development progressed.

There is considerable flexibility in the exact content of the individual project, but the levels are identified as: systems investigation, feasibility study, and systems development and implementation.

I regret to announce the resignation of William R. Bjerstedt as Associate Director, but I am pleased to announce the appointment of a new Assistant Director for Systems Development and Programming, James L. Linderman '64 and the reassignment of an existing Assistant Director, James A. Carrig, with responsibility for project coordination. Both of these individuals have been associated with the Office for more than five years.

DEAN L. JACOBY

**PLANNING OFFICE**

The major focus of our planning efforts this year has centered on translating the Institute's academic priorities into physical planning alternatives and the means required to achieve the goals established.

We have accelerated our facilities programming and design review efforts, maintained the tempo of an ambitious space change program, developed further our planning systems group, which has begun to provide techniques for dealing with both long-standing and new planning problems, and continued our intensive community relations efforts with both direct and indirect support of community planning and development programs in Cambridge and Boston.

A closer look at the activities of each of the groups in the Planning Office will show the broader scope and the diverse character of the work the Planning Office has performed in 1968.

**LONG-RANGE PLANNING**

The preparation of development plan alternatives and supporting studies has been the major concern of the long-range planning group this year.

A detailed study of the Institute's land resources and future requirements has been completed. It will serve as a key element in the evolution of a development strategy that must concern itself with the satis-
faction of Institute goals, the impact on the economy of the community, the steps necessary to ameliorate any adverse effects on the economy of our city due to institutional growth, and the means of generating new taxable investment to support the community in the future.

An analysis of past, present, and future Institute population has been completed and will serve to support long-range plans for a physical expansion of the M.I.T. community.

A comprehensive housing needs study has been completed which projects the housing requirements of the M.I.T. community to 1980 and outlines the resources and schedules necessary to accomplish this vital part of M.I.T.'s development program. In addition, an intensive study of the special housing and social needs of our graduate community was undertaken this year and will be completed shortly.

A major study of parking, circulation, and transportation requirements for the M.I.T. community has been under way throughout the year. We have been fortunate in having the aid of Emeritus Professor Alexander J. Bone in these studies; his expert knowledge in the field of transportation and traffic planning has been invaluable in helping us grapple with this most vexing problem.

The Planning Office has also continued the search for ways to improve our teaching environment. We have been studying the Institute's classroom resources, their utilization and environmental quality. We have been particularly concerned with the development of criteria for improving the classrooms we have, as well as those we design in the future. Among our efforts to explore different approaches to classroom design, the Planning Office, with the Student Committee on Environment, cosponsored a student competition for classroom design. Several of the ideas suggested by the students were used by a student designer in an experimental classroom design for Room 7-102.

A number of special studies were undertaken in connection with the Wellesley-M.I.T. Exchange Program. Transportation scheduling and a survey of potential participants were completed under the able direction of Peter T. VanAken, who served on the joint committee and provided the necessary staff planning services. This experience prompts me to suggest that the assignment of a Planning Office staff member to those Institute or faculty committees whose tasks include physical or operational planning issues, might be of considerable value. The committees, who most often work without assistance, would have the help of a supporting staff member; and the Institute's over-all planning effort would be enriched by a deeper understanding of the constantly developing and changing ideas of the Institute community.
VICE PRESIDENT, ORGANIZATION SYSTEMS

FACILITIES PROGRAMMING AND DESIGN REVIEW

Major academic projects consumed the energies of this group this year. A program for the Electrical Engineering and Communications Research Building was completed, along with four separate grant proposals to public agencies requesting funds for this major project. The largest single building undertaken by the Institute thus far, it will be located along Vassar Street and will bring together the electrical engineering community now widely dispersed throughout the Institute.

A program for the addition of two floors to the Hydrodynamics Building (Building 48) was prepared. Construction of this addition should be under way during the summer of 1968.

Programming studies were begun for several other projects including a new physics building, a chemical engineering building, architecture and planning, and major renovations for the Department of Mathematics.

The review of design proposals presented by architects is a highly critical phase in the development of a new Institute facility, second in importance only to the preparation of the Institute's building program requirements. It is at this point that careful analysis of the design proposals can determine the degree to which the Institute's program has been fulfilled. These reviews were conducted for design proposals prepared for MacGregor House, the Electrical Engineering and Communications Research Facility, the Massachusetts Avenue Crossing Project, renovations of undergraduate and graduate housing, residences for the Burton-Conner House Master and the Dean of Residence, the renovation of Burton-Conner House, the Hydrodynamics Laboratory, an indoor tennis facility, a proposal to expand the Hayden Gallery, renovations in Walker Memorial, the lobby of the Vannevar Bush Building, and 15 landscape projects including Eastgate, McCormick Hall East, the Julie Fassett Garden and the Eastman Court.

SPACE ADMINISTRATION AND PLANNING

Every school and almost every department is involved each year in the planning of space changes. Few programs represent as accurate a barometer of the vitality of the Institute as does the space change program. It reflects the changing needs of a vigorous community. The degree to which we can respond to these needs is a test of the flexibility of the physical plant of the Institute, a spirit of cooperative compromise and our judicious use of financial resources.

More than 75 major and minor changes to existing space were in progress or were completed during the fiscal year 1968. The Planning
Office, working in close liaison with the Physical Plant design section, faculty, students, and staff conducted the determination of requirements, preliminary estimating, scheduling, negotiation, budget preparation, accounting, monitoring and general administration for these space changes.

Greater attention is being placed on space changes which will become possible during the next five years as a result of new building construction. The allocation of space to activities which can best use these increased resources is the principle aim of the Committee for Research and Space Planning. The Planning Office provides the primary staff support for this committee.

Basic records of all space in the Institute are maintained by the Planning Office. Data concerning approximately 15,000 rooms and about five and one-half million square feet of usable space is constantly reviewed and updated. During the past year, more than 6,000 additions or changes were made to such records. These records are used daily as an important planning tool and are now available to the Institute community in summary form.

PLANNING SYSTEMS

This year a total information system for M.I.T. building space came closer to reality. For all practical purposes, all space on campus has been inventoried, thus for the first time establishing a significant and accurate data base for M.I.T. planning. We have begun to distribute the space inventory reports to individual departments and offices according to the particular administrative needs of each. A library of space inventory summary reports has been devised for the individual needs of schools and administrative offices.

The Civil Engineering Systems Laboratory culminated its research effort by supplying the Planning Office with a computer framework within which our future inventory and utilization studies may be carried on. The task of adjusting the system to fit our specific needs is now under way.

Other space inventory-related efforts that took place during this year included the submission of a completed physical facilities inventory to the Department of Health, Education and Welfare. Concurrently, we have been working on a project that will produce an accurate calculation of the gross building areas of all M.I.T. buildings.

Preliminary work has begun in establishing a computerized scheduling and reporting technique for tracking the planning phase of the many building projects that fall within the Planning Office's area of responsibility.
Considerable effort has been devoted this year to the design, processing and analysis of questionnaires prepared for the purpose of studying housing and parking problems at M.I.T. We have as a result a far more precise understanding of these important areas which affect all of the Institute community.

COMMUNITY RELATIONS

As the City of Cambridge moves ahead to deal with many of its planning and development problems, the community relations efforts of the Planning Office have grown accordingly. We have worked closely with the Office of Community Development and supplemented its limited staff by providing half-time assistance through Gordon L. Brigham, the Assistant Planning Officer for Community Relations. This procedure proved so effective that at the end of the year the Institute was requested to permit Mr. Brigham to take a leave of absence from his duties at M.I.T. so that he might devote all of his time to the development of the Community Renewal Program for Cambridge.

During the year, extensive studies and reports were prepared in support of a number of community projects including a market analysis that indicated the types and amounts of commercial space required by the Institute community. It should provide a sound basis for the programming of new commercial activities in the Kendall Square Project now being carried out by the Cambridge Redevelopment Authority. At the request of the Chairman of the Subcommittee on Housing of the Citizen's Advisory Committee, an analysis of the existing impact of M.I.T. on the Cambridge housing market and a general picture of future housing needs was prepared. This study, together with others, should provide the Citizen's Advisory Committee with an over-all view of the housing needs of our city and could lay the groundwork for a community housing policy that will address itself to the pressing housing needs of our city.

We have worked closely with the Committee on Community Service, attempting to deepen its insights into the Cambridge community and to broaden the scope of its effort.

The Planning Officer and members of the staff serve as regular members of the Cambridge Economic Opportunity Committee, the Alliance of Cambridge Settlement Houses, the Cambridge Community Services and a host of other community organizations active in community affairs. The Model Cities Planning Grant, which Cambridge has received, provides a great opportunity for imaginative and creative planning but there is still much to be done. The problem of the Inner
Belt Highway, for one thing, is still unresolved. Great efforts have been undertaken to analyze the current and future value of the highway as a transportation device. Equally great energies have been exerted in seeking ways of making the Inner Belt, should it be built, into a device for a positive program for the development of housing and community facilities.

The years ahead will see great activity and undoubtedly considerable strain among the various elements of the community. We have an unusual opportunity to demonstrate in our own city M.I.T.'s passion for creative and innovative solutions to complex urban problems. It will, however, take resourcefulness, sensitivity, imagination, patience, and a willingness to march to the special tempo of our city.

O. ROBERT SIMHA
DEPARTMENT OF AEROSPACE STUDIES

At the beginning of the academic year there were 51 cadets enrolled in the Air Force R.O.T.C. program. Of these, 30 were in the General Military Course (Basic Course), and 21 in the Professional Officer Course (Advanced Course).

The annual gaming exercise, POLMILEX V, was held on May 5, 1968, for members of the General Military Course. The game was built around a situation in South America.

During the academic year, six seniors, seven juniors and four sophomores were on Financial Assistance Grants, authorized by the R.O.T.C. Vitalization Act of 1964.

PERSONNEL

The appointment of Captain James L. Pettigrew as Associate Professor of Aerospace Studies was terminated in February, 1968. He was reassigned by the Air Force to training for service in Southeast Asia. During his appointment at M.I.T. he had worked with cadets in the Professional Officer Course and had developed an effective Corps Training Program. He also served as advisor to the Zeamer Squadron of the Arnold Air Society. Sergeant William E. Lee was appointed on June 1, 1967, as Detachment Sergeant Major with the academic rank of instructor. He replaced Sergeant Thomas P. Nagle, who was reassigned by the Air Force.

CADET ACTIVITIES

The Department sponsored three base familiarization visits during the year. On November 24, 1967, 12 cadets visited Andrews Air Force
OTHER OFFICES

Base for a briefing on the mission and organization of the Air Force Systems Command. Between January 30 and February 4, eight cadets received orientation briefings and visited the facilities at the Arnold Air Development Center, Tennessee; Robins Air Force Base, Georgia; and Dobbins Air Force Base, Georgia. On April 19, 1967, seven senior cadets visited L. G. Hanscom Field as guests of the Junior Officers' Council. They learned about life as a young lieutenant in Air Force research and development.

The cadets directed the annual Dining-In held on October 2, 1967. The guest speaker for the occasion was Colonel Henry Dittman, Base Commander, L.G. Hanscom Field, Bedford, Massachusetts. He spoke on concepts of professionalism and moral responsibilities of commissioned officers in the Air Force.

The combined commissioning ceremonies were directed by the Air Force R.O.T.C. detachment. Guest speaker was Brigadier General Leo A. Kiley, Commander, Office of Aerospace Research. He spoke of the challenges, rewards and responsibilities of the military officer today.

M.I.T. A.F.R.O.T.C. GRADUATES

During the academic year, eight cadets received commissions in the Air Force. Of these, one went to flying school upon graduation; two went to active duty as students under the Air Force Institute of Technology Program; and five were granted delays to complete studies for advanced degrees. The Air Force continues as a policy to grant educational delays to those individuals desiring to go immediately to graduate school and to assign graduates to fields requiring the specialties developed in their academic training.

GEORGE P. GAMACHE

DEPARTMENT OF MILITARY SCIENCE

Enrollment in Army R.O.T.C. continued to improve. There were 75 students enrolled at the end of the year compared with 63 at the close of 1967. This increase is primarily attributed to the continued revitalization of the program, which has created increased interest for students.

Nine seniors were commissioned during the year. One received a Regular Army commission in February and the remaining eight were commissioned in June. Of this group, one student was awarded a Regular Army commission. This individual also was awarded a special graduate school scholarship by placing in the top 5 per cent in national
One student completed the Military Science requirement, but commissioning will be deferred until September, 1968. Four of the graduating seniors were designated as Distinguished Military Graduates.

SCHOLARSHIPS
Four of the incoming freshmen were awarded the four-year Army R.O.T.C. Scholarships and one sophomore was awarded the two-year scholarship. This brings the total number of Army R.O.T.C. Scholarships at M.I.T. to 27.

PERSONNEL
The appointment of Lt. Colonel Jack R. Shields was terminated in July. He was reassigned to Alaska by the U.S. Army. His replacement, Colonel Marshall O. Becker, was appointed the new department head in July. Major John T. Myers' appointment also was terminated in July. He is reassigned to the Army Command and General Staff School. His replacement, Major Joseph G. McCoy, was appointed in June. Major James K. Pangman's appointment was terminated in June. He is reassigned to Vietnam. His replacement, Major Eugene R. Hunton Jr., was appointed in February. Major Leland E. Prentice, a 1967-68 M.I.T. special graduate student, was appointed in July. Additionally, Sergeant Major David J. Pawelski was promoted to the grade of Assistant Professor. Specialist Five Robert C. Tocci and Peter Rose were assigned for administrative duties in October and June, respectively.

JACK R. SHIELDS

DEPARTMENT OF NAVAL SCIENCE
There were five seniors in the graduating class this year, four of whom received commissions in the U.S. Naval Reserve in commissioning exercises on June 8, 1968. One received his commission upon completion of his academic program and was ordered to active duty in April, 1968. One of the newly commissioned Ensigns from the Naval R.O.T.C. program was granted a deferment from active duty to complete postgraduate education.

The freshman class had an enrollment of 14 Naval R.O.T.C. students. There were four sophomores, three juniors, and one senior on a leave of absence, making a total of 22 students remaining in the Naval R.O.T.C. unit after graduation. This unit also administered to 106 postgraduate officers of the U.S. Navy, U.S. Coast Guard, and the
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navies of six foreign countries, plus nine Naval Enlisted Scientific Education Program students.

As part of the continuing Navy Enlisted Scientific Education Program, three students completed the course of study and will be commissioned as Ensign, U.S. Navy, following graduation from Officer Candidate School at Newport, Rhode Island.

Captain Robert E. Stark and Commander Joseph A. Matthews will retire from the Navy on July 1, 1968. Captain Dean A. Horn will be the replacement for Captain Stark. A suitable replacement for Commander Matthews will maintain the present staff level of eight. Gunnery Sergeant Frederick P. Peterkin was relieved as Naval Science Instructor by Gunnery Sergeant Robert G. Mellen.

ROBERT E. STARK

ALUMNI ASSOCIATION

The 1968 Ernest T. Stewart Alumni Service Award was presented to the Alumni Association by the American Alumni Council at its recent conference in Miami. This is the Council's highest honor and is presented "for outstanding service rendered to an institution and to the cause of higher education through organized alumni effort." The M.I.T. Alumni Association met the criteria of the Award by its recently completed two-year self-study, which culminated in the publication of the Report of the Long Range Planning Committee.

Realizing that effective programs and organizational structures of the past will not necessarily suffice for the future, the Association took a comprehensive and in-depth look at itself. The study was conducted by a five-man Central Committee, under the chairmanship of John A. Lunn '17, and nine subcommittees. It resulted in recommendations of ways in which the Association could better serve the Institute in the years ahead. As stated by the judges, "The exemplary excellence of the Report extends its application beyond the Institute. In the broadest sense, the work of the Alumni Association's diligent leadership offers a renewed opportunity for students, faculty, trustees and alumni 'to mobilize behind education the full strength of organized alumni support.'"

The Technology Review also shared in the honors presented at the meeting of the American Alumni Council and again placed among the top ten alumni magazines. It was also cited for achievement in the areas of continuing education, the alumni, and cover design. In addition, the May issue was chosen for special recognition "for a special issue focusing on the inroads of our technological culture upon our natural environment."

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ALUMNI ASSOCIATION

The 1967 Alumni Seminar, Cities in Crisis, was particularly noteworthy and timely and reflected M.I.T.'s concern for the expanding urban environment in which we live. For three days distinguished faculty members and outside experts lectured and discussed with the participants the important aspects of our cities. The Seminar's impact is with us even now, and a large number of M.I.T. Clubs are still asking for speakers and programs growing out of it. This year invitations were extended by the faculty committee to M.I.T. faculty and their wives. Their attendance resulted in a greater interaction of alumni and faculty and an opportunity for more alumni to meet with faculty members.

In October, the Eighth National Alumni Officers Conference was held in San Francisco. This was the first time a location away from Cambridge was chosen, and it was this meeting that attracted a greater percentage of alumni who had never attended before. Alumni and their wives who live in the San Francisco area were invited to the Awards dinner, and the result was a renewed pride in their relationship to M.I.T.

This year, too, saw another innovation — the Student-Alumni weekend. This unique program grew from a volunteer undergraduate committee effort which was completely without M.I.T. administration or Association staff initiative. The alumni were, indeed, honored and pleased to have been invited to live with undergraduates and spend a weekend exchanging ideas and experiences.

Two classes held highly successful reunions on campus this year, and the many favorable comments indicate an increasing interest in campus reunions. This is a particularly healthy trend, because M.I.T. revisited provides a first-hand view of the rapidly changing and expanding physical environment, and an opportunity to sense and balance the improving cultural environment with the growth of the educational program.

THE ALUMNI FUND

Under the aegis of Howard L. Richardson '31, Alumni Fund Board Chairman, and Kenneth S. Brock '48, Director, 1967-68 was the fifth consecutive record-breaking year for receipts and the third for the number of donors. There were 18,771 donors who contributed $2,875,356, and for this progress we were honored to receive national recognition in the form of an award for Improvement from the American Alumni Council. The Fund's programs progressed in each category. Particularly significant, and holding much future promise, were the formation of Area Councils in major metropolitan areas, effective use of telephone solicitation, and the development of a Senior Class Gift.

On Alumni Day, substantial gifts from the principal reunion classes
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(1918, 1928 and 1943) were announced. In all, these reunion gifts (representing five-year accumulations) amounted to just under $800,000. Twelve hundred alumni were present at the luncheon, and it was at that time that the 50-year class boasted a 95 per cent participation in their reunion giving and announced separately that 30 members of the class had included M.I.T. in their estate plans, which will result in an estimated $1,230,000 for the Institute in future years.

TECHNOLOGY REVIEW

Volume 70 (1967-68) represented a second year of effort to strengthen the magazine and place it in a position to compete for readership with more generally circulated journals of modern science and technology and their implications. This effort took several directions:

1. Continuing emphasis on excellent editorial content. The volume included two special issues, "Cities in Crisis," which was developed from the 1967 Alumni Seminar, and "Technology and Our Environment," as well as a large number of other distinguished original papers.

2. Development of a totally new typographical format. The new design by Ralph M. Coburn '47 has given the Review visual distinction.

3. Continuing emphasis on advertising sales. In cooperation with two magazines at Harvard University, we have developed a Cambridge Alumni Group for local advertising, and we have worked to strengthen our national representation through American Alumni Magazines. Richard F. Wright, Advertising Manager, has increased his promotional activities in behalf of the Review, and the results, though disappointing in relation to recent years, must be viewed against the background of uncertainty in the advertising industry and declining magazine advertising which characterized the year.

4. The Review's normal circulation was augmented this year by about 7,000 alumni who were not current Alumni Fund contributors — the two most recent graduating classes, non-contributors in the principal reunion classes, and others judged to be of special concern to the Alumni Association and the Institute for various reasons. The response has been good, and a readership survey initiated at the end of the year will give more quantitative measures of the Review's impact on its various groups of readers. A modest effort to develop non-alumni circulation for the Review has resulted in the addition of at least 500 subscribers for Volume 70, and a much more extensive effort of this kind is planned for 1968-69.

5. The Review's Editorial Advisory Board has been formed, and its first meeting was held during the spring. Already it is clear that the
members will be of greatest assistance to the *Review* as its plans develop during the next few years, and we are grateful to each of them for his interest and commitment to us.

**M.I.T. CLUBS**

The Alumni Clubs have shown growth in spirit and interest this year under the leadership of the new Alumni Club Advisory Board. For the first time, a special Conference for Club Presidents was held in Cambridge. This offered an opportunity to discuss club matters with the Advisory Board and Association officers. Regional conferences were held in Philadelphia and Dallas, while the M.I.T. Florida Festival and Mexico City Fiesta drew many alumni together.

This year 83 members of the Institute's staff and the Alumni Council recorded a total of 210 M.I.T. Club visits. These represented meetings of 45 different M.I.T. Clubs.

**ALUMNI CENTER OF NEW YORK**

During 1967-68 the Alumni Center of New York continued to serve as a focus for all alumni activity in the metropolitan area. More than 500 alumni participated in activities on behalf of the Institute or the Association, and more than 5,800 alumni and friends attended 55 events. The first all-M.I.T. evening at Philharmonic Hall, honoring Dr. and Mrs. James R. Killian, Jr., attracted an audience of 2,600. The Northern New Jersey Club, with the close cooperation of the Alumni Center, sponsored the first major presentation in the area of the M.I.T. Symphony Orchestra, at which there was an attendance of 750.

**ALUMNI ROLLS**

In October, the 1967 *Alumni Register* was published. It contained alphabetical and geographical listings of the living and deceased alumni on the rolls as of June 30, 1967, plus present and former members of the Institute's Faculty and administrative staff. As of June 30, 1968, there were on the rolls 57,110 living alumni and 18,294 deceased.

**STAFF CHANGES**

Peter Gwynne resigned as Managing Editor of *Technology Review* to become Science Editor of the *Boston Herald Traveler*. Douglas F. G. Haven '52 left the staff of the Alumni Fund to enter private industry. Robert Hagopian '47 and Roy A. Johnson '50 were appointed Associate Directors of the Alumni Fund, and Ann Peterson joined the Alumni Association staff as Administrative Assistant.
PRINCIPAL PROFESSIONAL HONORS
AND ACTIVITIES OF THE STAFF

INSTITUTE PROFESSORS

CHARLES S. DRAPER
Distinguished Public Service Medal, National Aeronautics and Space Administration.
Exceptional Civilian Service Award, U.S. Air Force.

HAROLD E. EDGERTON
Richardson Medal, Optical Society of America.

EDWIN H. LAND
Honorary degree of Doctor of Humane Letters, Williams College.
Frederic Ives Medal, Optical Society of America.
Kulturpreis, Photographic Society of Germany.

CHIA-CHIAO LIN
John von Neuman Lecturer, Society for Industrial and Applied Mathematics.

PAUL A. SAMUELSON

FRANCIS O. SCHMITT
Honorary degree of Doctor of Laws, Juniata College.
Honorary degree of Doctor of Science, Michigan State University.

CYRIL S. SMITH
Member, Committee on Science and Public Policy, National Academy of Sciences.

C. RICHARD SODERBERG
De Laval Medal, Royal Academy of Engineering, Stockholm, Sweden.

VICTOR F. WEISSKOPF
Honorary degree of Doctor of Science, University of Montreal.

JEROME B. WIESNER
National Human Relations Award, National Conference of Christians and Jews,
The Travelers Insurance Company.
Recognition Award, University of Michigan.
The Sesquicentennial Award, University of Michigan.
PROFESSIONAL HONORS AND ACTIVITIES

SCHOOL OF ARCHITECTURE AND PLANNING

DEPARTMENT OF ARCHITECTURE

ALBERT G. H. DIETZ
Honorary Member of American Society for Testing and Materials.

DEPARTMENT OF CITY AND REGIONAL PLANNING

BERNARD J. FRIEDEN
Member, Board of Directors, Planners for Equal Opportunity.

JOHN T. HOWARD
Chairman, Advisory Committee to state Department of Commerce and Development on Revision of Planning Laws.

SCHOOL OF ENGINEERING

GORDON S. BROWN
Honorary degree of Doctor of Engineering, Stevens Institute of Technology.
Chairman, Commission on Engineering Education.

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

RAYMOND L. BISPLINGHOFF
Distinguished Service Medal, National Aeronautics and Space Administration.

WALTER M. HOLLISTER
Member, Technical Committee on Astrodynamics, American Institute of Aeronautics and Astronautics.

JAMES E. MCCUNE
Fellow, American Physical Society.

RENE H. MILLER
Member, National Academy of Science and Engineering.
The Klemin Award, American Helicopter Society.

ROBERT C. SEAMANS
Goddard Trophy.

EDWARD S. TAYLOR
Gas Turbine Division Award, American Society of Mechanical Engineers.

LEON TRILLING
Co-chairman, Sixth International Symposium in Rarefied Gas Dynamics.
Delegate, Third All-Union Congress of Pure and Applied Mechanics.

WALLACE E. VANDEVELDE
Member, Technical Committee on Guidance and Control, American Institute of Aeronautics and Astronautics.

H. PHILIP WHITAKER
Member, Guidance and Control Panel, Advisory Group for Aeronautical Research and Development, NATO.

LAURENCE R. YOUNG

DEPARTMENT OF CHEMICAL ENGINEERING

RAYMOND F. BADDOUR
Chairman, Gordon Research Conference on Separation and Purification.
Member, Editorial Board, Separation Science.

P. L. THIBAUT BRIAN
Member, Committee on Program and Member, Committee on Research, American Institute of Chemical Engineers.

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HONORS AND AWARDS

THOMAS B. DREW
Max Jakob Memorial Award, American Society of Mechanical Engineers and American Institute of Chemical Engineers.

ARTHUR EVANS JR.
Vice Chairman, Film Loops Subcommittee and Member, Educational Projects Committee, American Institute of Chemical Engineers.

LAWRENCE B. EVANS
Preceptorship, United Engineers and Constructors, Inc.

EDWIN R. GILLILAND
Member, Board of Visitors, Department of Chemistry, Tufts University.
Member, Industrial and Professional Advisory Council, Pennsylvania State University.
Chairman, Engineering Section; Chairman, Division III; and Member, Finance Committee, National Academy of Sciences.
Member, Advisory Board, A.I. Ch.E. Journal.
Member, Management Advisory Council, Oak Ridge National Laboratory, Atomic Energy Commission.
Consultant, President's Science Advisory Committee.

ALLAN S. HOFFMAN
Member, Editorial Advisory Board, Polymer Engineering & Science.

HOYT C. HOTTEL
Chairman, American Committee on Flame Research.
Member, National Academy of Sciences.
Member, Committee on Fire Research and Member, Advisory Panel to the National Bureau of Standards, National Research Council.
Founders Award, American Institute of Chemical Engineers.

HERMAN P. MEISSNER
Member, Evaluation Committee for Ion Adsorption Processes, Office of Saline Water.

EDWARD W. MERRILL
Member, Scientific Advisory Council, American Heart Association.

HAROLD S. MICKLEY
Vice Chairman, Committee on Education, American Institute of Chemical Engineers.

ROBERT C. REID
Chairman, Lecturer Nominating Committee and Chairman, Technical Program Committee, 1968 Meeting, American Institute of Chemical Engineers.

EDWIN W. SALZMAN
Markle Scholar in Academic Medicine.

ADEL F. SAROFIM
Secretary, American Flame Research Committee, International Flame Research Foundation.

CHARLES N. SATTERFIELD
Member, Editorial Advisory Board, Industrial and Engineering Chemistry.

THOMAS K. SHERWOOD
Chairman, Committee on Air Quality Management, National Academy of Sciences — National Academy of Engineering.
Chairman, Research Symposium and Member, Freezing Review Committee, Office of Saline Water.
Member, Industrial and Engineering Chemistry Committee, American Chemical Society.
PROFESSIONAL HONORS AND ACTIVITIES

GLENN C. WILLIAMS
Member, National Defense Education Act Fellowship Review Board.
Member, Facilities Grants Review Board, U.S. Office of Education.
Member, Panel on Electrically Powered Vehicles, U.S. Department of Commerce.

DEPARTMENT OF CIVIL ENGINEERING

J. MELVIN BIGGS
Clemens Herschel Award, Boston Society of Civil Engineers.

PETER S. EGLESON
Chairman, Committee on Education and Research in Hydrology, Universities Council on Water Resources.
Member, Committee on Methods of Analysis and Data Networks, Urban Water Resources Research Program, American Society of Civil Engineers.

DONALD R. F. HARLEMAN
Desmond Fitzgerald Medal, Boston Society of Civil Engineers.
Fellowship of the John Simon Guggenheim Memorial Foundation.

ALAN M. HERSHFDORFER
Chairman, Special Interest Group on Planning, Architecture, Civil Engineering, and Urban Data Systems, Association for Computing Machinery.

RONALD C. HIRSCHFELD
Chairman, Organizing Committee, Fourth Pan American Conference on Soil Mechanics and Foundation Engineering.

ARTHUR T. IPPEN
Honorary degree of Doctor of Engineering, Technical University at Karlsruhe, Germany.
Member, Committee on International Education, American Society for Engineering Education.

RUSSEL C. JONES
Vice President, Massachusetts Section and Vice Chairman, Committee on Mechanical Properties of Materials, American Society of Civil Engineers.
Member, Executive Committee, Division of Materials Science, American Society for Testing and Materials.

T. WILLIAM LAMBE
U.S. delegate and Vice President, Pan American Soil Mechanics Conference.
Chairman, Committee on Session Programs, Soil Mechanics and Foundation Division, American Society of Civil Engineers.

MARVIN L. MANHEIM
Academic Vice President, Transportation Research Forum.

FREDERICK J. MCGARRY
Best Paper Award at 23rd Annual Conference, Reinforced Plastics/Composites Division, Society of the Plastics Industry.

FRED MOAVENZADEH
Member, Committee on Design and Member, Committee on Soils, Geology, and Foundations, Highway Research Board.

FRANK E. PERKINS
Member, Executive Committee, Hydraulics Section, Boston Society of Civil Engineers.

KENNETH F. REINSCHMIDT
Legion of Merit and Meritorious Service Award, Military Traffic Management, United States Army.
HONORS AND AWARDS

DEPARTMENT OF ELECTRICAL ENGINEERING

MICHAEL ATHANS
Program Chairman, 1968 Joint Automatic Control Conference.
Associate Editor, Automatica.

ROGER W. BROCKETT
Chairman, Stability Theory Committee, Group on Automatic Control, Institute of Electrical and Electronics Engineers.
Member, Program Committee, Joint Automatic Control Conference.

CHARLES K. CRAWFORD
Vice-Chairman, New England Section, American Vacuum Society.

WILBUR B. DAVENPORT JR.
Member, Educational Activities Board, Institute of Electrical and Electronics Engineers.

MICHAEL L. DERTOUZOS
J. Browder Thompson Memorial Prize, Institute of Electrical and Electronics Engineers.

ROBERT G. GALLAGER
Fellow, Institute of Electrical and Electronics Engineers.

BERNARD GOLD
Member, Administrative Committee, Group on Audio and Electroacoustics, Institute of Electrical and Electronics Engineers.
Member, Committee on Speech Communication, Acoustical Society of America.

JOSEPH C. R. LICKLIDER
Alumni Award, Washington University.

MARVIN L. MINSKY
Fellow, American Academy of Arts and Sciences.
Fellow, Institute of Electrical and Electronics Engineers.

WALTER A. ROSENBLITH
Member, President's Committee on Urban Housing.
Member, Board on Medicine, National Academy of Sciences.
Member, Committee on Brain Sciences, National Research Council.
Member, Princeton University Advisory Council for Psychology.
Member, Administrative Committee G-EMB, Institute of Electrical and Electronics Engineers.

JACK P. RUINA
Fellow, American Academy of Arts and Sciences.

FRED C. SCHWEPE
Chairman, Stochastic Systems Committee, Group on Automatic Control, Institute of Electrical and Electronics Engineers.

ALEXANDER SMAKULA
Special Technical Award, American Society of Magazine Photographers.

LOUIS D. SMULLIN
Fellow, American Physical Society.

JOHN E. WARD
Fellow and Vice Chairman, Joint Computer Conference, Institute of Electrical and Electronics Engineers.

BRUCE D. WEDLOCK
Chairman, Group on Electron Devices, Boston Chapter, Institute of Electrical and Electronics Engineers.

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PROFESSIONAL HONORS AND ACTIVITIES

DEPARTMENT OF MECHANICAL ENGINEERING

FORBES T. BROWN
Chairman, Fluidics Committee, American Society of Mechanical Engineers.

STEPHEN H. CRANDALL
Secretary, Applied Mechanics Division, American Society of Mechanical Engineers.

JAMES A. FAY
Chairman, Plasmadynamics Committee, American Institute of Aeronautics and Astronautics.
Member, Research and Technology Advisory Subcommittee on Fluid Mechanics, National Aeronautics and Space Administration.

WILLIAM R. FERRELL
Member, Administrative Committee, Group on Man-Machine Systems, Institute of Electrical and Electronics Engineers.

LEON R. GLICKSMAN
Member, Fluid Mechanics Committee, American Society of Mechanical Engineers.

GEORGE N. HATSOPOULOS
Member, Research and Technology Advisory Committee on Space Power and Electric Propulsion, National Aeronautics and Space Administration.

JAMES C. KEECK
Member, Physics Panel, Air Force Office of Scientific Research.

ROBERT W. MANN
Member, Advisory Council, National Joint Braille Authority.
Member, Committee on Prosthetics Research and Development, National Academy of Sciences — National Research Council.

EGON OROWAN
Carl Friedrich Gauss Medal, the Braunschweigische Wissenschaftliche Gesellschaft.

RONALD F. PROBSTEIN
Member, Fluid Dynamics Committee, American Institute of Aeronautics and Astronautics.
Founding Editor, Journal of Statistical Physics.

ERNEST RABINOWICZ
Member, Committee on Basic Research advisory to the U.S. Army Office, National Research Council.

WARREN M. ROHSENOW
Fellow, Heat Transfer Memorial Award; and Member, Board of Communications, American Society of Mechanical Engineers.

ASCHER H. SHAPIRO
Fellow, American Society of Mechanical Engineers.
Member, Board of Governors, Technion — Israel Institute of Technology.

THOMAS B. SHERIDAN
Editor, Institute of Electrical and Electronics Engineers Transactions on Man-Machine Systems.

PREScott A. SMITH
Fellow, American Society of Mechanical Engineers.
American Society of Mechanical Engineers Member, Sectional Committee on Dimensional Meteorology, U.S.A. Standards Institute.

EMERY I. VALKO
Fellow, American Institute of Chemists.

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HONORS AND AWARDS

DAVID G. WILSON
Chairman, Process-Industries Division and Program Chairman, Annual Conference, Gas-Turbine Division, American Society of Mechanical Engineers. Chairman, Boston Chapter, Volunteers for International Technical Assistance.

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

MORRIS COHEN
Member, National Academy of Sciences.

JOHN F. ELLIOTT
Fellow, Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers. Member-at-large, Engineering Division, National Research Council.

THEODOULOS Z. KATTAMIS
First Prize, Association of Alumni, Liège University, Belgium.

THOMAS B. KING
Secretary, Education and Development Council, American Society for Metals.

SIMON C. MOSS
Fellowship of the John Simon Guggenheim Memorial Foundation.

ROBERT MICHAEL ROSE
Executive Committee, Boston Chapter, American Society for Metals.

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

MARTIN A. ABKOWITZ
Chairman, Seakeeping Session, American Towing Tank Conference, Ottawa, Canada, June, 1968.

WILLIAM A. BAKER
Honorary Member, Boston Marine Society.

ALFRED A. H. KEIL
Chairman, Laboratory Advisory Board for Naval Ships, Naval Research Advisory Committee.

DEPARTMENT OF NUCLEAR ENGINEERING

MANSON BENEDICT
Fellowship of the John Simon Guggenheim Memorial Foundation.

GORDON L. BROWNELL
Vice Chairman, Isotopes and Radiation Division, American Nuclear Society.

ELIAS P. GYFTOPOULOS
Fellow and Vice Chairman, Aerospace Division, American Nuclear Society.

KENT F. HANSEN
Chairman, Mathematics and Computation Division, American Nuclear Society.

NORMAN C. RASMUSSEN
Honorary degree of Doctor of Science, Gettysburg College.

THEOS J. THOMPSON
Vice Chairman, Reactor Physics Division, American Nuclear Society.

THOMAS O. ZIEBOLD
National Secretary, The Electron Probe Analysis Society of America.

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

DEPARTMENT OF ECONOMICS

FRANKLIN M. FISHER
PROFESSIONAL HONORS AND ACTIVITIES

EVERTT E. HAGEN
Fellow, American Academy of Arts and Sciences.
President, Association for Comparative Economics.

MAX F. MILLIKAN
President, World Peace Foundation.

FRANCO MODIGLIANI
Member, Executive Committee, American Economic Association.

KARL SHELL
Ford Foundation Faculty Research Fellowship.

ROBERT M. SOLOW
Vice President, American Economic Association.

DEPARTMENT OF HUMANITIES

RICHARD M. DOUGLAS
Fellow, American Academy of Arts and Sciences.

GERALD B. DWORKIN
Summer Fellowship, National Endowment for the Humanities.

DAVID M. EPSTEIN
Composers Award, American Society of Composers, Authors, and Publishers.
Member, National Council, American Society of University Composers.
Member, Artists Advisory Board, New England Lyric Theatre.
Member of the Board, Young Audiences, Boston.

ROY LAMSON
Member, American Academy of Arts and Sciences.

THOMAS H. D. MAHONEY
Chairman, Massachusetts State Fulbright Committee.

BRUCE MAZLISH
Social Science Research Council Fellowship.

HUSTON SMITH
Phi Beta Kappa Visiting Scholar.

DEPARTMENT OF MODERN LANGUAGES AND LINGUISTICS

NOAM A. CHOMSKY
Honorary degree of Doctor of Literature, University of London.

WILLIAM N. LOCKE
President, National Federation of Modern Language Teachers Associations.
Chairman, Linguistics in Documentation Study Group, International Federation for Documentation.

DEPARTMENT OF POLITICAL SCIENCE

HAYWARD R. ALKER JR.
Executive Committee, Mathematical Social Science Board.

LINCOLN P. BLOOMFIELD
Member, State Department Advisory Committee on Peacekeeping.

FREDERICK W. FREY
Co-winner, 1967 Pi Sigma Alpha Award, American Political Science Association.

WILLIAM W. KAUFMANN

EUGENE B. SKOLNIKOFF
Member, Committee on Council Affairs and Secretary, Section K, American Association for the Advancement of Science.
Member, Committee on Younger Members, Council on Foreign Relations.
HONORS AND AWARDS

DEPARTMENT OF PSYCHOLOGY

RICHARD M. HELD
Chairman, Experimental-Psychology Study Section, National Institutes of Health.
Fellow, American Academy of Optometry.

HARVEY J. KARTEN
Charles Judson Herrick Award, The American Association of Anatomists.

HANS-LUKAS TEUBER
Foreign Member, French Psychological Society.
Honorary member of the faculty, National Institute of Neurology of Mexico.

Sloan School of Management

ARNOLD E. AMSTUTZ
Ford Foundation Research Fellowship.
Sperry-Hutchinson Fellowship.

JOHN F. COLLINS
Dr. Ray Johns Youth Service Award, Boston Youth Activities Commission.
1968 Distinguished Public Administrator of the Year Award, Boston Chapter, American Society of Public Administrators.

JAY W. FORRESTER
Fellow, American Academy of Arts and Sciences.

JAY R. GALBRAITH
Vice Chairman, College on Organization, Institute of Management Sciences.

BILLY E. GOETZ
Chairman, Engineering Economy Division, American Society for Engineering Education.

MASON HAIRE
Co-winner, McKinsey Foundation award for best research design.

DAVID B. MONTGOMERY
Vice Chairman, College on Marketing, Institute of Management Sciences.
Sub-Editor, Computer Applications, Journal of Marketing Research.

STEWART C. MYERS
First Prize for paper submitted to Program for Studies of the Modern Corporation, Columbia University.

EDWARD B. ROBERTS
Member, National Council, Institute of Management Sciences.
Member, Air Force Scientific Advisory Board.
Member, Department of Commerce Technical Advisory Board.

EDGAR H. SCHEIN
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Member of the Board, Executive Development Center, Sterling Institute.
Member, North Atlantic Research Group on Management.

School of Science

ROBERT A. ALBERTY
Member, American Academy of Arts and Sciences.

Department of Biology

EUGENE BELL
Clerk of the Corporation, Marine Biological Laboratory, Woods Hole.
PROFESSIONAL HONORS AND ACTIVITIES

Cecil E. Hall
Honorary degree of Doctor of Laws, University of Alberta, Canada.

Salvador E. Luria
President, American Society for Microbiology.

Sheldon Penman
Executive Committee, Cell Study Section, National Institutes of Health.

Alexander Rich
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Fellowship of the John Simon Guggenheim Memorial Foundation.

Lisa A. Steiner
Member, American Association of Immunologists.

Isadore Amdur
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Carl W. Garland
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Richard C. Lord
Honorary member, Society of Applied Spectroscopy.

Nicholas A. Milas

Ki-iti Horai
Okada Prize, Oceanographical Society of Japan.

Patrick M. Hurley
President, Geochemical Society.

Gene Simmons
Fellow, American Geophysical Union.

M. Nafi Toksoz
Secretary, Eastern Section, Seismological Society of America.

Edward B. Curtis
Fellowship of the John Simon Guggenheim Memorial Foundation.

Eric Reissner
National Science Foundation Senior Postdoctoral Fellowship.
Member, Membership Committee, American Academy of Arts and Sciences.

Hartley Rogers
National Science Foundation Senior Postdoctoral Fellow.

Gian-Carlo Rota
Distinguished Visiting Professor, University of Colorado.
Chief Editor, Advances in Mathematics.
Member, Council, American Mathematical Society.
HONORS AND AWARDS

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DEPARTMENT OF NUTRITION AND FOOD SCIENCE

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Fellow, American College of Dentists.

SANFORD A. MILLER
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Chairman, Subcommittee on Cell and Organ Culture and Storage, National Academy of Engineering.

PAUL M. NEWBERNE
Member, Nutrition Council, American Feed Manufactures Association.
Member, Research Council, American Veterinary Medical Association.

RICHARD J. WURTMAN
John Jacob Abel Award, American Society for Pharmacology and Experimental Therapeutics.
Member, American Society for Clinical Investigation.
Member, Editorial Board, Endocrinology.

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Member, American Association of Physics Teachers.

ARON M. BERNSTEIN
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SANBORN C. BROWN
Fellowship of the John Simon Guggenheim Memorial Foundation.

ROBERT J. KOLENKOW
Member, Editorial Board, Review of Scientific Instruments.

PHILIP MORRISON
Honorary degree of Doctor of Science, Case-Western Reserve University.

PHILIP M. MORSE
Member, Advisory Panel on Operational Research, Organization for Economic Cooperation and Development.
Member, Regional Medical Program Review Committee, National Institutes of Health.

WILLIAM K. ROSE
Member, International Astronomical Union.

GEORGE L. SISCOE
Member, Space and Atmospheric Physics Committee, American Institute of Aeronautics and Astronautics.

BERTRAM E. WARREN
Fulbright Lecturer, College de France, Paris.

ADMINISTRATION

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Vice President, American Society for Engineering Education.
Chairman, Engineering College Research Council.

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PROFESSIONAL HONORS AND ACTIVITIES

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Secretary, Boston Chapter, American Society of Safety Engineers.
Chairman, Campus Safety Association, Higher Education Section, National Safety Council.

VINCENT A. FULMER
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Trustee, The Children's Museum of Boston.

HOWARD W. JOHNSON
Eleanor Roosevelt Key Award, Roosevelt University.

JAMES R. KILLIAN, JR.
Man of the Year, National Association of Educational Broadcasters.
George Foster Peabody Broadcasting Special Education Award.
Bronze Beaver Award, M.I.T. Alumni Association.

G. EDWARD NEALAND
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MEDICAL

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Secretary, New England Dermatological Society.

CHARLES S. KEEVIL JR.
Fellow, American College of Physicians.

FRANCIS X. MASSE
President, New England Chapter, Health Physics Society.

MELVIN H. RODMAN
President, Massachusetts Thoracic Society.

ROBERT F. TILLEY
Fellow, American College of Physicians.

OTHER DEPARTMENTS AND LABORATORIES

ALAN R. BENENFELD
Program Chairman, New England Chapter, American Society for Information Science.

NELSON Y. KIANG
Third Annual Beltone Award for Research in the field of hearing.

PHILIP LIEBERMAN
Member, Technical Committee on Speech, Acoustical Society of America.

FRANCES R. LUBOVITZ
Secretary, Executive Committee, Cataloguing and Classification Section, Resources and Technical Services Division and Membership Committee, American Library Association.

WARREN S. MCCULLOCH
Honorary degree of Doctor of Sciences, University of Illinois.
President, American Society for Cybernetics.

PAULA MENYUK
Fellow, American Speech and Hearing Association.

LAWRENCE G. RUBIN
Member, Editorial Board, Review of Scientific Instruments.
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INSTRUMENTATION LABORATORY

RICHARD H. BATTIN
Member, Research and Technical Subcommittee on Control, Guidance, and Navigation, National Aeronautics and Space Administration.
Corresponding Member, International Academy of Astronautics.
Member, Technical Committee on Computer Systems, American Institute of Aeronautics and Astronautics and Associate Editor, *Journal of the American Institute of Aeronautics and Astronautics*.

JOHN W. HURSH

JAYNE PARTRIDGE
Member, Technical Committee, Reliability Physics Symposium, Institute of Electrical and Electronics Engineers.

RALPH B. TRUEBLOOD
I.B. Laskowitz Gold Medal Award, New York Academy of Sciences.

LINCOLN LABORATORY

FRANK J. BACHNER
U.S. Army Commendation Medal.

MARIO D. BANUS
Chairman, Boston Section and Member, Publication Committee, Electrochemical Society.

STEVEN L. BERNSTEIN
Vice Chairman, Boston Chapter, Group on Communication Technology, Institute of Electrical and Electronics Engineers.

CARL BLAKE
Chairman, Boston Chapter, Group on Microwave Theory and Techniques and Member, Editorial Review Board, *I.E.E.E. Proceedings*, Institute of Electrical and Electronics Engineers.

JACK CAPON
Chairman, Boston Chapter, Group on Information Theory, Institute of Electrical and Electronics Engineers.

MITCHELL S. COHEN
Chairman, New England Chapter, Thin Film Division, American Vacuum Society.

ROBERT N. DAVIS
Board Member, Users of Automatic Information Display Equipment.

MILDRED S. DRESSELHAUS
Abby Rockefeller Mauzé Visiting Professor.

JOHN V. EVANS
Fellow, Institute of Electrical and Electronics Engineers.

GERARD A. GALLAGHER
Member, Ad Hoc Committee for the American Institute of Aeronautics and Astronautics Study of Space Simulation Problems.
Member, U.S. Air Force Ad Hoc Committee for Study of High Power Xenon Lamp Development.
PROFESSIONAL HONORS AND ACTIVITIES

WILLIAM J. GETSINGER
Chairman, Technical Committee on Computer-Aided Design of Microwave Techniques, Group on Microwave Theory and Techniques, Institute of Electrical and Electronics Engineers.

EDWARD G. GOULART
Chairman, Boston Chapter, American Society for Industrial Security.

ELIS A. GUDITZ
Director, New England Chapter, American Association for Contamination Control.

HAROLD L. KASNITZ
Member, National Board of Governors, Society of Photo-Optical Instrumentation Engineers.

J. J. GERALD MCCUE
Editor *I.E.E.E. Spectrum*; Member, Editorial Board, *I.E.E.E. Proceedings*; Member, Publications Board, Institute of Electrical and Electronics Engineers.

JAMES W. MEYER
U.S. Air Force Commendation for Meritorious Civilian Service.

GORDON H. PETTENGILL
Vice President of Commission 17 (The Moon), International Astronomical Union.

CHARLES M. RADER
Chairman, Subcommittee 30.4 (Audio-Concepts), Institute of Electrical and Electronics Engineers.

DANA A. REGILLO
Member, Massachusetts Professional Engineers.

LEON J. RICARDI
Chairman, Technical Program Committee, 1968 International Symposium, Group on Antennas and Propagation, Institute of Electrical and Electronics Engineers.

ABRAHAM M. RICH
Member, Program Committee, American Society of Mechanical Engineers.

MILTON L. ROSENTHAL
President, Western Middlesex Chapter, Massachusetts Society of Professional Engineers.

HARRY E. STANLEY
Miller Research Fellowship.

ERNEST STERN
Member, Technical Committee for NEREM '68 and for Microwave Theory and Techniques Symposium for 1969.

EDWARD P. WAREKOIS
Chairman, Electronic Materials Committee, American Institute of Mining and Metallurgical Engineers.

HERBERT G. WEISS
Member, Editorial Board, *I.E.E.E. Proceedings*, Institute of Electrical and Electronics Engineers.

BRUCE K. WILLARD
Treasurer, Boston Chapter, National Association of Accountants.