# Massachusetts Institute of Technology
# Bulletin

---

# Report of the President and the Chancellor
# 1971-1972

# Massachusetts Institute of Technology Bulletin

---

# Report of the President and the Chancellor 1971-1972

Massachusetts Institute of Technology Bulletin
Volume 108, Number 3, September, 1973

Published by the
Massachusetts Institute of Technology
77 Massachusetts Avenue, Cambridge, Massachusetts,
five times yearly in August, September, November, December, and March.
Second class postage paid at Boston, Massachusetts.

Issues of the Bulletin include
COURSES AND DEGREE PROGRAMS
GENERAL CATALOGUE
REPORT OF THE PRESIDENT AND THE CHANCELLOR
TREASURER'S REPORT
SUMMER SESSION CATALOGUE

Send undeliverable copies and changes of address to
Massachusetts Institute of Technology, Room 7-111
Cambridge, Massachusetts 02139.

# Corporation

Honorary Chairman: James R. Killian, Jr.
Chairman: Howard W. Johnson
President: Jerome B. Wiesner
Chancellor: Paul E. Gray
Vice President and Treasurer: Joseph J. Snyder
Secretary: John J. Wilson

## LIFE MEMBERS

Bradley Dewey, Vannevar Bush, James M. Barker, Thomas C. Desmond, Marshall B. Dalton, Donald F. Carpenter, Crawford H. Greenewalt, Lloyd D. Brace, William A. Coolidge, Robert C. Sprague, Charles A. Thomas, David A. Shepard, George J. Leness, Edward J. Hanley, Cecil H. Green, John J. Wilson, Gilbert M. Roddy, James B. Fisk, George P. Gardner, Jr., Robert C. Gunness, Russell DeYoung, William B. Murphy, Laurance S. Rockefeller, Uncas A. Whitaker, Julius A. Stratton, Luis A. Ferré, Semon E. Knudsen, Robert B. Semple, Irénée du Pont, Jr., Eugene McDermott, James R. Killian, Jr.

## MEMBERS

Albert H. Bowker, George P. Edmonds, Ralph F. Gow, Donald A. Holden, H. I. Romnes, William E. Hartmann, Frank R. Milliken, Henry E. Singleton, Gregory Smith, Thornton A. Wilson, James A. Champy, Elisha Gray II, William R. Hawthorne, Jerome H. Holland, Breene M. Kerr, Carl M. Mueller, Harold E. Thayer, Jeptha H. Wade, Virgilio Barco, William S. Brewster, Ralph M. Davison, John C. Haas, Philip H. Peters, Mary F. Wagley, D. Reid Weedon, Jr., Paul M. Cook, William S. Edgerly, J. Kenneth Jamieson, Kenneth H. Olsen, George W. Thorn.

## REPRESENTATIVES FROM RECENT CLASSES

Laurence Storch, James A. Hester, Christina H. Jansen, Michael V. Sawyer, Pamela T. Whitman.

## PRESIDENT OF THE ALUMNI ASSOCIATION

Paul V. Keyser

## REPRESENTATIVES OF THE COMMONWEALTH

Governor: His Excellency, Francis W. Sargent
Chief Justice of the Supreme Judicial Court: Honorable G. Joseph Tauro
Commissioner of Education: Neil V. Sullivan

## LIFE MEMBERS, EMERITI

Alfred L. Loomis, Harlow Shapley, Walter J. Beadle, Irving W. Wilson, Thomas D. Cabot, Ralph Lowell, Gwilym A. Price, James H. Doolittle, Robert A. Lovett, Horace W. McCurdy.

# Contents

# President and Chancellor

We close our first year in the stewardship of M. I. T. with enthusiasm. We are buoyed by a sense of modest accomplishment, a deep confidence in the basic integrity and quality of M. I. T., and the dedication of the Institute's faculty, staff, and students to the goal of continued excellence in knowledge and learning. Most importantly, we emerge from our first year with a firm conviction that a major challenge remains for M. I. T. and its graduates, a challenge from the nation and the world to find ways of applying the knowledge and skills of science and technology to the pressing problems of our society, many of them wholly new human and social problems.

The progress in the past year of each department, School, and laboratory is described in detail by our colleagues in their annual reports. In this prologue to their reviews we will attempt to look toward the future of M. I. T. as a whole. Our goals are to identify those recent trends and present activities in which are embodied the elements of tomorrow's Institute and to evaluate the Institute's strengths and needs in meeting the challenges now before it.

For the new administration— the Provost, the Chancellor, the President, and our colleagues— the past year was, at once, a period of taking stock, of getting acquainted with new responsibilities, of seeking new directions, and of gathering momentum for efforts already begun. It was also a time that required the intensive involvement of the senior officers of the Institute in fiscal issues of major importance and persistent urgency. The relentless rise in costs due to inflation, the impact of rising tuition on our students and their families, as well as on our resources for financial aid, and the decline of Federal support for graduate education have been particularly vexing concerns and have absorbed a major portion of our energy and time. The primary issue is not that of short-run solvency or stability. Rather, it is the challenge of managing the growth of costs and the allocation of resources in ways that encourage innovation and creativity in education now, while simultaneously strengthening the fiscal basis of M. I. T. for future generations of students and faculty. We have made a start in understanding and dealing with these problems. There is clear evidence after a year that the short-range fiscal problems can be managed in ways that do not weaken our essential activities in education, in research and scholarship, and in service. Longer term concerns, dominated by a persistent difference in the growth rates of expenses and income, will continue to have a high priority for us.

## Criticism and Leadership: The Modern Dilemma of the University

By far the most heartening feature of the past year has been the progress made on important intellectual fronts, progress which is reflected in major shifts of learning opportunities through the development of new academic programs and new research activities.

Underlying most of our new efforts is the growing conviction that, in spite of the current anti-science, anti-technology mood in many quarters, continued progress and the creation of a more acceptable world will require major new technical developments as well as modifications in social patterns. Furthermore, there is a growing realization that the problems for which science and technology have been blamed stem not so much from the development of technologies but from their profligate use by a society too slow to appreciate

that what is highly beneficial on a small scale could be very damaging when employed massively and, consequently, might require social inventions to match the technical developments.

Foresight and innovation lacking, the temperature of social unrest has risen, producing a dissatisfaction with many aspects of the status quo. This is a worldwide phenomenon, but several aspects of our society make the situation more acute in this country than in many others. Because we are the technological leaders of the world, many of the troublesome side effects of a technological society occur here first. Classical examples are, of course, pollution, urban decay, and traffic congestion;but there are also more subtle, more difficult attitudinal problems, such as boredom in highly automated manufacturing plants or the feeling that the interests of people are being sacrificed to the development of impersonal bureaucracies and data processing systems.

In addition, two special problems have added greatly to the internal stresses in our society and especially in the university— the black struggle for admission to the full range of opportunity in American life and the continuing cancer of the Vietnam war.

To a greater or lesser degree, socio-technical, racial, and war-related problems, as well as others posed by size and complexity, have made an impact on most social organizations, including the various parts of government, industry, and the educational system. Because all of these major units of society play a role in the modern industrial state, they have all been criticized to some degree for the appearance of the unanticipated painful and frightening features of the modern world. Government is criticized because it is expected to deal with social problems as they emerge and has not done so quickly enough; industry is criticized because it has made the creations of technology widely available and consequently is increasingly expected to anticipate or assume concern for the safety and long-range effects of its products.

The educational system, particularly the university, is challenged on many fronts. Colleges and universities have been expected to accept the greatly enlarged and more diverse group of students now seeking higher education. The size of this group and the wide diversity of its intellectual background has strained the abilities of universities to maintain high quality in educational programs and to preserve those intellectual traditions which they harbor and pass on to their students. At the same time, universities have been expected to augment their intellectual capital. Only thus could they provide leadership both in helping to solve the pressing problems of the times and in ensuring that graduates would be prepared for life in a rapidly evolving and unpredictable society. The expectations for preservation, on the one hand, and renewal, on the other, conflict in part; and it is not surprising that few people have been happy with the results. Students have frequently viewed the universities as perpetuators of the status quo. Many older citizens have tended to view them as breeders of radical thought. Both groups have criticized them bitterly.

Uneasiness in the society at large has been inevitable, and, to some extent, protest and criticism have helped to focus attention on important problems. The presence of disruptive protest in our society was an almost existential shock to many, and it took some time to fully absorb its meaning. But protest and criticism do not provide solutions, and the need for creative leadership through education stands out.

Universities everywhere are searching for their particular contributions to the current social challenge. Some have been weakened by the pressures of crisis; many — ours among them — have emerged stronger and healthier from the trials of internal strife. The course ahead may be less dangerous, but it is certainly more difficult, for the goal is not mere survival.

There is now a widespread realization that there is a need to consciously manage the tremendous power which technology makes available, while remaining sensitive to the impact of new technology on the natural and man-made world. We realize that the task in the years ahead is not only to find solutions to many pressing problems but to do so in a way that does not generate different problems of greater complexity. In fact, one of the immediate tasks is to handle problems such as pollution without creating a whole set of new crises in related fields such as energy or agriculture.

To make any progress, one must first come to regard the current dilemma not as a result of massive failures to be castigated but as the opening of new opportunities. The dilemma has resulted from a great success in applying technology to human purposes and from an unprecedented achievement in making technological advantages widely available to people everywhere. Mankind has not been prepared for the suddenness of this success. We have to learn in a very short period how to consider the collective effects and long-range consequences of actions, as well as their first-order effects. We must learn to do this without losing the advantages of large-scale technology. This has already begun to happen. It can be seen in the restraints that are placed on activities which could have an adverse impact on the environment and in the emphasis that we see in the growing movement for corporate social responsibility. It is also highly visible in the career choices of students, in the legislation of local, state, and Federal governments, and in the international efforts that are developing to understand the nature of man's impact on the natural world. It is particularly exciting for us at M. I. T. to see this effect in the changing academic and research interests of both faculty and students.

## Teaching and Research: Achievement in Perspective

The response of the faculty and student body at M. I. T. to the needs of contemporary society can be seen in new academic and research programs. Traditional academic disciplines and established professions are by no means obsolete, but they do not necessarily provide the most effective nor the most powerful means of focusing our talents on the great social issues of the day. Most Schools and departments at M. I. T. have been struggling to identify an intellectual core which is more appropriate to today's needs than were earlier formulations. This struggle takes place in two areas — in teaching programs and in research. Effective new academic programs require complementary creative intellectual effort to support them; and new intellectual fields, in turn, depend on coming generations of professionals who have been trained in new ways to meet new challenges.

For example, in focusing engineering skills on today's world, there has developed at M. I. T. a new engineering perspective that adds a "needs analysis" and an "impact analysis" to the traditional concepts of engineering solutions. Thus, the points of view of the social sciences and of systems analysis are added to the conventional technical scientific knowledge which forms the underpinning for the profession.

A similar broadening of interests in other fields has generated many interdisciplinary and inter-School efforts, both in research and in academic programs. Engineering, the physical and biological sciences, the social sciences, and the humanities are building new channels of communication with one another. The new emphasis has also opened up many desirable avenues of collaboration with industry and government.

For some, the response to social needs appears too slow; for others, it is obviously too fast. Many people find frustrating the slow rate at which we have been able to clarify our tasks, but considering the complexity of these issues, halting progress should not be surprising.

The great danger remains that cumulative effects of the social confusion and economic limitations will inhibit the sound evolution of educational programs to fit the new needs.

We have been somewhat disappointed at the rate at which we have been able to attract outside support for many of the new programs at the Institute. Furthermore, the shortage of M.I.T. venture capital caused by necessary budgetary stringency has forced cutbacks in some existing programs and has required everyone to work a little harder on them. This makes it difficult to find extra time and internal resources for the establishment of new programs. Yet, there has hardly been a time in the history of the Institute when challenges were greater and the opportunities for academic, technical, and social contributions more numerous. Some support for most of the worthwhile experiments has been found. We hope this will continue to be possible.

*Educational Programs*

How and what to teach? These are hardly new questions, especially for an institution that has been the intellectual leader in its field for most of its history. Yet today these questions are regarded as more urgent by students and faculty alike than they have been for many decades. The local concerns are but a part of a worldwide reassessment of the character and role of higher education which, in turn, is but a part, albeit an important part, of the major transformations occurring in the society.

The last two decades have been a period of continuous growth and development during which time the American university population more than doubled and the graduate student population grew even faster. The M.I.T. student body nearly doubled in size. Improvements in the quality of elementary and secondary education for a large number of students made it possible (in fact necessary) to upgrade and diversify the content of the courses in the universities, specifically in physics, chemistry, biology, and mathematics. In turn, this focus on content generated an intense interest on the part of a substantial number of faculty in teaching methods and the social environment of learning. As a result, there has been a wave of experimentation and research focusing on contextual aspects of the learning process, as well as on content. The initial work has led a number of faculty members and students to full-time professional careers in educational innovation and research.

Throughout this evolutionary period, two themes have been prominent at M.I.T.: 1) the urge to provide a more flexible learning environment and 2) the effort to provide more mature educational experiences for the students, consistent with their abilities and their needs. As part of the effort to provide greater flexibility, there has evolved a series of optional routes through most of the core subjects, designed to make it possible for most students to engage the subject matter in the way that best suits their preparation and learning style. The experimental programs, reported in earlier years, included a variety of self-paced and tutorial options in freshman seminars, as well as three quite special experimental groups— the Experimental Study Group (E.S.G.), the Unified Science Study Program (U.S.S.P.), and the Concourse Program in which radically different educational experiences were made available. The new opportunities also included the possibility of a degree without specification in several departments, which increased the opportunity for individually planned upper-year programs.

Greater flexibility in an M.I.T. undergraduate education is also advantageous for those undergraduates who see M.I.T. as an ideal preparation for careers in newly emerging aspects of medicine, law, and education. Professional school admissions requirements create additional demands on the student, demands which are somewhat different from the usual preparation for a career in science or engineering. To assist those students, a pre-professional counseling service has been created. As we gain experience with this initial effort, this service may be expanded to provide career development assistance in other areas.

In order to provide more mature experiences for students, we have been trying to make it possible for them to interact in a professional way with the other members of the

Institute family — students, faculty, and staff. Through the highly successful Undergraduate Research Opportunities Program (U.R.O.P.), a substantial portion of the undergraduate student body achieved a close collaborative association with members of the faculty, working together on ongoing projects. Such encounters encourage intellectual commitment and self-direction and provide a nearly ideal climate in which students can develop educational self-sufficiency and intellectual independence — habits of mind that are crucial to lifetime effectiveness and satisfaction. This program is now extended to include collaborative opportunities in a number of off campus institutional settings, including industrial, government, health, and community organizations. We comment further on this important development in a later section of this report.

Finally, the Independent Activities Period in January continues to provide a new dimension to educational activities through the freedom it offers for individual projects, intensive subjects, and exploratory programs that do not fit into the normal academic calendar.

These experiences were sufficiently exciting to lead a Special Task Force on Undergraduate Education to study more deeply both the experimental programs and the recommendations of the M.I.T. Commission on Education (1969-70). In reporting to the Faculty at the close of the previous academic year (1970-71), the Special Task Force made three specific recommendations: that attention to undergraduate education be emphasized by creating a post of Dean for the Academic Program; that a more intimate faculty-undergraduate student relationship be established through a seminar/research activity which might occupy as much as 25 per cent of each student's time during his undergraduate years; and that careers in education, as well as a continuing interest in educational research and development, be facilitated through the establishment of an Education Division. The recommendations were examined this year by the Committee on Educational Policy which endorsed them in a series of reports to the Faculty. They were discussed at special Faculty meetings and endorsed in principle at the end of the year. The administration was given a mandate to implement these changes to the extent that resources and other limitations permitted. Planning for these new initiatives began before the spring term was ended, and it is expected that implementation will begin during the fall term of the 1972-73 academic year.

In addition to these Institute-wide programs stressing alteration in the social environment of learning, the several Schools continued with high interest the reformation of teaching programs reflecting their new intellectual directions. In the School of Engineering, teaching programs which complement new research efforts on the interface between engineering and social policy have been initiated in the Departments of Civil Engineering, Aeronautics and Astronautics, and Ocean Engineering. These teaching programs combine more familiar engineering subjects with systems analysis, pertinent aspects of law and economics, and policy-analysis studies. The School of Science has introduced a new School-wide degree without specification based on the highly successful experiment conducted for several years by the Department of Earth and Planetary Sciences. This option of a non-specialized education in the sciences will provide students with a solid scientifically based liberal education, as well as offering them ideal preparation for a future professional career in the sciences. In the School of Management, new public policy programs have been initiated with particular emphasis on the management of health delivery systems and health care planning. The School of Architecture and Planning has similar concepts, and, in particular, a special effort has been placed on strengthening the capability of the School in the area of natural ecology. A new program will place emphasis on the impact of current environmental policies, the intergovernmental constraints affecting the implementation of those policies, and the problems of assessing environmental situations and requirements. As in the School of Engineering, there is a strong desire to link the educational process with societally related activities, which in this case means breaking down the walls between the university and community through

the mechanism of field-linked education and research programs. In addition, the major programs — the HUD Minority Internship Program and the Community Fellows Program — provide a means for substantial minority group participation in the advanced programs of the School of Architecture and Planning.

The educational activities of the joint Harvard-M.I.T. Program in Health Sciences and Technology entered their second year, accepting a second group of juniors and seniors drawn from the two schools. There are now approximately 50 students in the program. Fourteen new subjects have been created in conjunction with this new effort, and many students from areas other than the joint Program at both Harvard and M.I.T. take advantage of them.

*Research Activities*

Research trends at the Institute reflect the growing awareness of the complex problems industry, government, and the educational system face in this period when society, and the criteria by which the technological innovations are judged, are changing rapidly. To a large extent, the problems which are now receiving our attention are very different from those we are accustomed to solving and, therefore, demand new kinds of solutions — a task requiring creative intellectual efforts of considerable scope and intensity. Many of the problems which now claim our research interest cannot be approached through a single discipline or in a strictly academic mode. They are problems integral to the complex social fabric of our time, whose very identification and definition may be dependent upon a true collaboration between the university and people in other sectors of society. The solutions of these problems depend not only on the intellectual analysis which the university could provide but also on the degree to which those who can implement solutions are convinced of their appropriateness and feasibility. Also, a new criterion has been added to the requirements for a "successful" solution — that its second-order and long-term effects on the society at large be benign.

The evolution of research programs in new and socially related disciplines is the foundation on which the development of academic programs in those fields rests. Obviously there can exist no effective graduate program without a research base to support it, and even an effective undergraduate program in any evolving discipline must ultimately have such a foundation. We have been pleased with the progress thus far because it establishes to a considerable degree the pace at which new academic programs can emerge. Some highlights of the newly evolving research efforts are discussed briefly below.

The research aspects of the joint Harvard-M.I.T. Program in Health Sciences and Technology have continued to develop satisfactorily. An eighteen-member sponsoring committee under the joint chairmanship of Mr. Charles Francis Adams and Dr. George W. Thorn has been established and is now functioning. During the year, a $5 million grant was received from the National Institutes of Health for a program in biomaterials, as well as a substantial grant for the construction of teaching laboratories from the James and Lynelle Holden Fund. Funds for endowment, and research program support in a variety of areas, are now being sought.

Especially notable during the past year has been the School of Engineering's expansion of research activities related to social applications of technology. Drawing on the strong and growing base of engineering science in many departments, there have been important developments in uses of water resources, ocean engineering, transportation systems, environmental problems, and energy problems (including investigations of electrical power). Under the leadership of Dean Alfred A.H. Keil, several interdepartmental groups have been formed, pooling resources for more effective research and teaching in the fields of transportation, pollution, and energy. In addition, the School has pioneered in the sponsorship of a very successful Sea Grant Program, now funded at over $1 million annually.

Also of great interest is a new Center for Policy Alternatives based within the School of Engineering but reaching out both to other Schools within M. I. T. and to operating agencies outside the Institute. The Policy Center will develop alternatives of both action and policy for those social problems which relate strongly to technology or which would benefit from a meaningful application of technology.

During the past year, the Lincoln Laboratory enjoyed a steady and significant technical progress. Traditional program areas such as communication and strategic technology, advanced electronic technology, radar techniques, and seismic discrimination continue essentially unchanged in scope.

The number of new programs being undertaken by the Laboratory is growing, both in terms of size and variety— a very encouraging trend. A major new air-traffic control program under Federal Aviation Administration sponsorship calls for the Laboratory to act as the primary technical agency over the next five years in the development of a Discrete Address Beacon System, which will substantially upgrade existing air-traffic control system capabilities. This program, together with other civilian air-traffic control activities, now comprises about 15 per cent of the Laboratory's total effort.

The ambulatory health care program continues to progress. Procedures designed to permit paramedical personnel to play a larger role in the delivery of health care have undergone successful experimental testing in clinical environments. A self-paced learning system developed by the Lincoln Laboratory is now under test.

June 1, 1972, marked the completion of Draper Laboratory's second year as an independent division of the Institute, and a major portion of the attention and effort of the Board of Directors and Officers continues to be directed toward the very complex business of designing an effective method of divesting the Laboratory from M. I. T. As this is being written, we are close to agreement with the government agencies, who also sponsor research on campus at Lincoln Laboratory, and with the Draper Laboratory regarding the financial implications of divestment to both M. I. T. and the Laboratory.

During the past year the distribution of Draper Laboratory sponsorship was 67 per cent military, 31 per cent NASA, and 2 per cent other. For the forthcoming year, military sponsorship will account for about the same fraction of Laboratory research, NASA programs will decline modestly, and other programs will increase to about 3 per cent of the total. The level of "other" programs in absolute terms remains modest, but the increasing trend is heartening. There continues to be a broadening of the base of applications for the Laboratory's technological capabilities. Continued growth in biomedical engineering, for example, has been recognized by the establishment of a new organizational entity within the Laboratory— the Divison of Medicine, Biology, and Health Care Programs. Other involvements in oceanography, industrial process control, and medical instrumentation, to cite but a few, continue to flourish and give great future promise.

To enhance and expand its educational activities, a new Division of Education has been formed within the Draper Laboratory which will seek to establish ties with other institutions which can benefit from the unique resources and capabilities of the Laboratory.

In the area of Institute-wide research policy, the principal focus has been on stimulation of the process of innovation and on mechanisms for quickening the transfer of technological advances from laboratory to general public use. The most significant manifestation of this effort was the founding of a new corporation, the M. I. T. Development Foundation, Inc., chartered by the Commonwealth of Massachusetts on April 3, 1972. The new organization is experimental in nature and will serve to assist in the formation of new enterprises and to provide a communications link among government, industry, and sources of venture

capital interested in the development and application of technology developed at M. I. T.

While we are pleased with the scope and progress of research efforts relatively new to M. I. T., we are also encouraged by the improvement of support in M. I. T.'s more traditional areas of work, particularly in engineering and science. This does not mean that all important areas of research on campus are now adequately funded; quite the contrary, since in many important areas of basic science, engineering, and the social sciences, austerity is very much the order of the day. There is still a severe shortage of support for graduate students. Lack of funds for new equipment inhibits work and has made it necessary to terminate some activities prematurely in order that those continuing activities are assured of adequate financing. Nonetheless, the situation is discernibly better, and the outlook for the future is brighter. The present projections indicate an on-campus research volume next year (Fiscal Year 1972-73) of approximately $75 million, an increase of approximately 9 per cent over the previous year, which represents a substantial programmatic increase after effects of inflation have been taken into account. At Lincoln Laboratory research volume increased to $68 million this year, about 16 per cent higher than last year, and will probably climb to $72 million for Fiscal Year 1973. Research volume at the Draper Laboratory, presently about $50 million, is likely to increase in Fiscal Year 1973 to about $60 million, although much of the increase will flow through to industrial subcontractors.

## The Arts at M.I.T.

Although creative arts have always flourished at M. I. T. as part of the academic program and of the extracurricular life, 1971 was a year in which two great forward steps were taken through the establishment of a Corporation Visiting Committee on the Arts and the creation of a Council for the Arts at M. I. T.

M. I. T. has nurtured an extraordinary range of artistic activities which are housed in several departments and Schools. In the Department of Humanities, music assumes many dimensions, both in the formal work in the classroom and in the extensive participation by students and other members of the community in performance. There is also creative writing, both poetry and prose, theater and film. In the Department of Architecture, one finds art history and criticism, design, photography, and cinema. The Departments of Humanities and Metallurgy and Materials Science share a program in archeology and ancient technology. The Center for Advanced Visual Studies, interested in affecting the shape and vision of the environment, sponsors a broad range of sculptural and design activities. There is also a faculty Committee on the Visual Arts responsible for art exhibitions and for recommendations regarding the physical environment of the Institute.

Each of these activities is an important element in its sponsoring department, yet each has certain needs which can be best served by interaction between them and simultaneous consideration of their roles and requirements. The new Corporation Visiting Committee on the Arts was created to fill part of this need and to allow the administration and the Corporation to consider these efforts coherently without removing them from the academic environments in which they have grown and now flourish. The Visiting Committee, chaired by Dr. James R. Killian, Jr., has a membership of 11 other people who represent the broad spectrum of the arts at M. I. T.

The Council for the Arts at M. I. T. is planned to fill yet another need that stems from the dispersed nature of the creative arts programs, namely, the lack of an alumni constituency with whom to interact and from whom to draw support. This new Council is comprised of a nationally based, select group of men and women who are alumni, friends of the arts, faculty, staff, and students. Members, appointed by the President for three-year terms, will work closely with the President and Faculty in an advisory role. They will relate to

the M.I.T. Corporation, the faculty Committee on the Visual Arts, and to other Institute groups concerned with the role of the arts in education. The Council will complement and support the activities of the Corporation Visiting Committee on the Arts and will be supported in all of its activities by the M.I.T. staff. Ultimately the Council is expected to have approximately 100 members, who will convene at M.I.T. at least once a year and who also will be asked to participate in regional meetings in their communities. Subcommittees dealing with specialized activities in the arts will be appointed by the Council.

## Prospects and Challenges

The complexities and, indeed, perplexities that confront us as we consider M.I.T.'s future reflect the complicated and rapidly changing conditions of our world and, perhaps more importantly, the evolving values and attitudes of people toward these changing conditions.

There is no doubt that in this environment of complexity, advanced technology will continue to play a dominant role. For more than a century the Institute and its graduates have had an important hand in the development of technological knowledge and skill. It is our conviction that in the times ahead M.I.T. men and women will have an equally creative contribution to make. Moreover, we feel an added responsibility that stems from our understanding and special competence in science. Our goal as educators, and to some degree as models, should be to help prepare young people to find a constructive, creative, and satisfying role in meeting the needs of society— a humbling task, indeed, when one considers the full scope of these needs.

We are less sure than we may have been in the past just how our educational contributions should manifest themselves. We can point to exciting programs of innovation in teaching and research development, which are efforts in the educational process aimed at both improving the M.I.T. educational scene and providing career opportunities for interested students and faculty. There are shifts in faculty research interests toward activities that contribute to the solution of the great socio-technical questions of the pivotal moment in which we live. These are movements that have gone on for many years but have received new impetus in the last decade. They were slowed, camouflaged, and refocused— some may say strengthened— during the years of student protest. They are now in full bloom. Pressing ahead on these developments for better learning and research with a foundation in science has been and continues to be M.I.T.'s cardinal purpose.

But the turbulent, rapidly evolving society places other major challenges before the Institute, challenges that have not been in the traditional realm of the university. We wish to identify here three such challenges and comment on each briefly.

First, M.I.T., together with other institutions in this society, must rethink and recast the structure of opportunity which we afford those who spend time with us— opportunity for individual satisfaction and self-fulfillment, opportunity for participation in affairs which affect them, opportunity for employment and subsequent advancement. All who study here and work here stand to benefit from greater attention to these basic human needs. Persons employed at the Institute require ready access to opportunities for advancement, as well as greater attention to their needs for personal and career development. Those who study here deserve an education which enriches the essential lifelong process of growth and educational self-renewal and places a premium on self-sufficiency and intellectual independence.

While these goals pertain to all members of the M.I.T. community, at this moment in time we have an especial responsibility to expand opportunities for members of minority groups and women at all levels of the Institute. We must not stand aside from the society as it struggles to consolidate the opportunities for a decent life that now exist. Indeed, we should be innovative and creative in our handling of these difficult problems with the hope

that, in so doing, we will point the way for others as well as enriching our own environment for all members of this community. We must put special emphasis on placing in significant positions at all levels competent women and members of minority groups with whom young people may identify professionally and personally. Our record of achievement in the past year has been significant but falls short of the standard that we have set for ourselves. We are taking steps to improve our means for meeting our pledge to the Federal government and, even more importantly, to ourselves.

A second major challenge is the need to relate the university to the local and national community, to attempt a working partnership between the academy and the society which sustains it. The traditional objective, to keep at a respectable distance and avoid interference, is no longer tenable. Like many of the topics discussed in this report, the critical dynamic between the urban university and the city is interdependence. It is relatively easy to identify and even assess the needs of urban America from a perspective of some remove. Scholars have done it for decades, recently with greater sophistication and often with compassionate understanding. It is yet another matter for a university to work effectively with community organizations, from state and local government agencies to neighborhood groups and advocate interests, in the mutual effort to create an ever more decent, responsive, and responsible society.

M.I.T. should count itself fortunate for the acceptance it has had in the Cambridge community. This is, of course, the result of arduous and sensitive work on the part of many staff and students and equally of a positive response from the community and its leaders.

The total range of M.I.T.'s activities in the local community is broad and far-reaching. In both research and action modes a stream of M.I.T. men and women flow into these activities. They come from the Joint Center for Urban Studies; from the departments in the School of Architecture and Planning; from the Urban Systems Laboratory; from the School of Management; from various departments in the School of Engineering; from Political Science; from Nutrition; and from many of our other departments, laboratories, and centers as well.

In addition to these academic efforts, a variety of community service programs, which for the most part have evolved in the past few years, have been undertaken in Cambridge and Boston by students, faculty, and staff. Finally, there are many other programs conducted by M.I.T. in its role as an important institutional citizen of this metropolitan area. Many of these projects are large and substantial, and several involve collaborative action with other universities and organizations in the Boston area.

Within all these various modes of relationships, M.I.T. remains keenly aware of its central purpose to create the best possible environment for teaching and learning. Thus, the Institute has sought to become associated with community activities in ways that contribute importantly and effectively to our students, as well as to the social purposes of the activity itself. We seek to have field-linked activities provide, particularly for students, a means of adding perspective to academic studies and research. Also, we are experimenting with a number of ways of improving the educational qualities of our relations with local agencies and organizations.

The Commonwealth of Massachusetts, as well as our local Cambridge community, faces severe economic problems, many of them related to the changing social and industrial issues facing the nation. Here, too, M.I.T.'s faculty and administration have been seeking to make a contribution, both through participation in governmental activities and through the support of industrial enterprise. This participation is increasing, although it is still modest. We are optimistic about our ability to do more, particularly in helping

Massachusetts make the most of science and technology in creating new industries and new jobs.

We hope the range of collaborations with our community will continue to grow to our mutual advantage, yet we recognize that there is still much to be done.

A third major challenge which we face in the months and years to come is the expansion of programs already begun, extending an M. I. T. education to people outside its usual borders, while simultaneously expanding the number and types of people who participate in the education of our students.

We have the opportunity to use modern technology as a means for reaching out beyond the classroom and the traditional limits of the educational encounter to offer greater educational opportunities to our alumni and others who might want it, as well as to our students and employees. Many members of the M. I. T. faculty and staff have been exploring the educational potential of technology for a number of years. We expect that such activities will continue, and as pilot techniques involving television, film, and computers are adopted by others at M. I. T., the advantages of technology will become as integral to education as are the current uses of books, blackboards, and lecture halls. Such technology is being used by the Center for Advanced Engineering Study in providing M. I. T. subjects in advanced and specialized areas to groups of engineers in a wide variety of organizations throughout the country. We hope that such initial efforts will grow and mature in the years to come.

Just as we can develop ways to make an M. I. T. education available to many, without limit of schedule or distance, so we hope to do the converse, to expand the range of people, institutions, and settings which can contribute to the education of those of us physically in Cambridge. Many important types of learning are not found in the classroom or laboratory-- even the most fully equipped or most strongly staffed classroom or laboratory. Many of our students want to learn what it feels like to be an engineer; how academic principles learned in a classroom or laboratory work in the "real world;" how to test themselves against the demands of the world of work, as opposed to the world of study. They want to work with people older than themselves and younger than themselves, people whose expectations for the world may be very different from their own. Providing our students this opportunity requires investigating the possibility that organizations other than our own may be the best place for them to spend significant amounts of time; it requires collaborative arrangements with such organizations so that they are adequately compensated for their efforts in educating our students; and it requires the development of methods to help a student grapple with his experiences and relate them to the more strictly academic part of his life.

There are several examples of initiatives taken in these directions by individuals and groups. In the past four summers, for example, we sponsored a number of urban action field projects, initiated in large measure by students and designed in most instances jointly by the participating students and the local agencies or neighborhood groups with whom the students worked in Cambridge or Boston.

The Undergraduate Research Opportunities Program, which has been the model for effective professional involvement — on a one-to-one basis — of students and faculty on campus, was expanded this year to include opportunities off campus, where professional supervision and faculty counsel combine to provide appropriate educational experiences for students in companies, hospitals, government agencies, and other work. There is virtually no limit to the opportunities for expansion of this program, provided the basic elements of quality work and faculty supervision are present.

As this report is written, a number of new ventures of educational opportunity are under

exploration. The Provost and the academic Deans are discussing the feasibility of non-regular appointments to the Faculty that would allow professionals from off campus to become clinical professors and field program supervisors with the suitable recognition and standing in the academic community that is required to facilitate and support their educational activities and contributions. There are discussions in many quarters about programs that would provide genuine career-sampling opportunities of the type afforded for years in our cooperative programs in some of the engineering departments. Clearly, more of our energy must go into activities and programs of this sort in the times ahead if we are to respond successfully to the needs of our students and of the professions. Our quality of counseling (the information, as well as the sampling of opportunities for diverse careers) must grow to reflect the demand for these services. A science-based education at M. I. T. is becoming, more and more, a suitable and desirable preparation for careers in medicine, law, and education. This requires a realistic and continuous liaison with institutions that support and utilize talent in these professions.

Improvement of internal opportunity, increased community participation, and new programs that reach outside the campus for cooperative educational arrangements are by no means the only challenges in prospect. To the individual student and the individual professor at the Institute, the outstanding challenge will always be to achieve the personal standard of performance and the personal goals that he sets for himself when he enrolls or begins to work here or, more immediately, when he enters the classroom, the library, or the laboratory every day. In annual reports that attempt to survey the macrocosm of the university, these atomistic goals and achievements tend to become submerged. But they are no less important. Indeed, it is the aggregate of these individual efforts that reflects the strength and the character of this institution. They need to be acknowledged and recognized as a primary reason for our existence.

The individual efforts and distinctions on the part of the faculty at M. I. T. have been many during the past year. Six members of the faculty were elected to membership in the National Academy of Sciences; several members of the Department of Humanities were honored with national awards for their contributions in the fields of music and literature; and faculty members in all Schools were recipients of departmental and Institute awards for both notable achievement in research and excellence in teaching. Of special note, during the year, was the appointment of Dr. Edwin R. Gilliland, Warren K. Lewis Professor of Chemical Engineering, to the distinguished rank of Institute Professor.

The past year marked also the retirement of eleven distinguished members of the faculty. Their years of service to the Institute and to their students will long be remembered and appreciated. They are Joseph Bicknell, Professor of Aeronautics and Astronautics; Robley D. Evans, Professor of Physics; Harold W. Fairbairn, Professor of Geology; Roland B. Greeley, Professor of Regional Planning and Director of Admissions; Everett E. Hagen, Professor of Economics and Political Science and Director of the Center for International Studies; Gyorgy Kepes, Institute Professor, who continues as Director of the Center for Advanced Visual Studies; Deane Lent, Professor of Mechanical Engineering; Klaus Liepmann, Professor of Music and Director of Music; Walter McKay, Professor of Aeronautics and Astronautics; Herbert H. Uhlig, Professor of Metallurgy; and Robert S. Woodbury, Professor of the History of Technology.

## Administration

In the fall of 1970, Howard W. Johnson announced his decision to relinquish the presidency and suggested that the trustees consider expanding the top leadership of M. I. T. This resulted in adding to the traditional presidency the post of Chancellor, as deputy to the President on all matters. As we have sought to understand and implement this new charter in our first year, we have discovered both the wisdom and the potential pitfalls of the new arrangement. Understandably, there was some duplication of effort as both of us

became acquainted with our varied duties. On balance, we feel that the Institute has gained from the doubling of effort and energy. We certainly have gained a great deal of encouragement and support from each other's presence at the helm. Looking to the year ahead, we have agreed that the President will concentrate his energy on plans and strategy for the Institute's future and on efforts to secure the resources – both faculty and funding – necessary for new and continuing programs. The Chancellor will carry the general management responsibilities for all Institute programs and operations, continuing his special interests in undergraduate education and student affairs. The Provost will continue as the senior academic officer for educational programs and research, working with the academic Deans and the interdisciplinary program directors.

In concluding this report, we wish to express our deep appreciation, both as a team and individually, for the responsive understanding and support that we have received from the members of the Corporation, the Faculty, the students, the staff, the alumni, and all the M. I. T. men and women whom we met and worked with throughout our first year in office. We are especially grateful to our administrative colleagues who have served with devotion and helped turn a difficult task into a rewarding and cheerful experience.

The past months saw several appointments to senior administrative positions that should receive special mention. Our first appointment, in July 1971, was Dean Alfred A. H. Keil to lead the School of Engineering. Dean Keil came to this post after five years as Chairman of the Department of Ocean Engineering where his vigor and imaginative plans had already begun to bear fruit with new academic curricula and a very significant Sea Grant Program, which will be formally recognized in a national convocation this fall. Professor Ira Dyer succeeded Dean Keil as Head of Ocean Engineering. In Architecture and Planning, the new Dean, William L. Porter, is a graduate of our own School where, as a Mellon Fellow and as a teacher, he has formally bridged the fields of architecture and planning in his own career.

Last spring, Dean Robert L. Bishop requested that he be relieved of his administrative duties in the School of Humanities and Social Science so that he might return to teaching and research in economics. We are fortunate to have as his successor Professor Harold J. Hanham, a distinguished historian, who will be taking up his duties in the spring of 1973.

Professor William N. Locke stepped down from his post as Director of the M. I. T. Libraries. He continues as Professor of Modern Languages and Director of Libraries, Emeritus. In addition, he assumes the duties of Foreign Study Advisor.

Dr. Carola B. Eisenberg succeeded Professor J. Daniel Nyhart as Dean for Student Affairs this past summer. Professor Nyhart served in the demanding post of the Dean with dedication and compassion, and his human qualities were much appreciated by M. I. T. students during three of the Institute's most critical years. He will continue to serve as Special Assistant to the Chancellor for preprofessional programs and as coordinator for law-related studies.

In concluding our first year in office, we owe a special debt of gratitude to the Chairman, Howard W. Johnson, and the members of the Executive Committee of the Corporation who have provided consistent and invaluable counsel and support to us on all of our activities. Finally, we wish to single out our closest colleague, Walter A. Rosenblith, who, in his new post as Provost and as a close friend and counsel, has been an essential addition to our team effort in the leadership of the Institute.

JEROME B. WIESNER, President

PAUL E. GRAY, Chancellor

# Statistics for the Year

The following paragraphs report briefly on the various aspects of the Institute's activities and operations during 1971-72.

## Registration

In 1971-72 student enrollment was 7,717, a decrease of 82 from the 7,799 enrolled in 1970-71. This total was comprised of 4,137 undergraduate and 3,580 graduate students.

Graduate students who entered M.I.T. last year held degrees from 316 colleges and universities, 178 American and 138 foreign. The foreign student population was 1,403 representing 18 per cent of the total enrolled. The foreign students were citizens of 99 different countries.

Degrees awarded by the Institute in 1971-72 included 1,068 Bachelor's degrees, 25 Bachelor of Architecture degrees, 700 Master's degrees, 50 Master of City Planning and Architecture degrees, 117 Engineer degrees, and 418 Doctoral degrees— a total of 2,378.

The number of women at M.I.T., both graduate and undergraduate, has increased continuously. In 1971-72, 698 full-time women students were at the Institute, compared with 604 in 1970-71. In September, 1971, 128 women freshmen entered M.I.T. In September, 1970, the number was 87. In 1971-72, 137 degrees were awarded to women, compared with 108 in 1970-71.

## Student Financial Aid

During 1971-72 the student financial aid program was again characterized by increases in total awards, in loans made, and in the amount of scholarship assistance. There was a small decrease in the number of individuals assisted.

A total of 2,007 undergraduates who demonstrated the need for assistance (52 per cent of the enrollment) received $2,795,982 in scholarship aid and $1,703,952 in loans. The total $4,499,934 represented no marked change in direct aid over last year.

Scholarship assistance was provided by the scholarship endowment in the amount of $1,657,593, by outside gifts for scholarships in the amount of $452,538, and by direct grants to needy students totaling $539,651. Scholarship assistance from M.I.T.'s own operating funds was not used during the year. The special program of scholarship aid to minority group students represented an additional $146,200 from specially designated funds. An additional 333 students (more than twice as many as in 1970-71) received direct grants from outside agencies, irrespective of need, in the amount of $526,487. Outside scholarship support thus totaled $1,518,676, a marked increase over last year's total. The undergraduate scholarship endowment was aided by the addition of new funds which represented an increase of $693,074 and which raised the principal of the endowment to $19,801,587.

Loans totaling $1,703,952 were made to needy undergraduates. Of this amount, $311,155 came from repayments to the Technology Loan Fund, $1,261,822 from the National Defense Loan Fund, and the remainder from other M.I.T. loan funds. An additional $567,965 was obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained $211,501 from the Graduate Loan Fund established to provide loans at prime commercial interest rate. As a lender under the Guaranteed Loan Program,

## FIGURE 1

## FINANCIAL AID TO UNDERGRADUATE STUDENTS FROM ALL SOURCES, 1962-1972

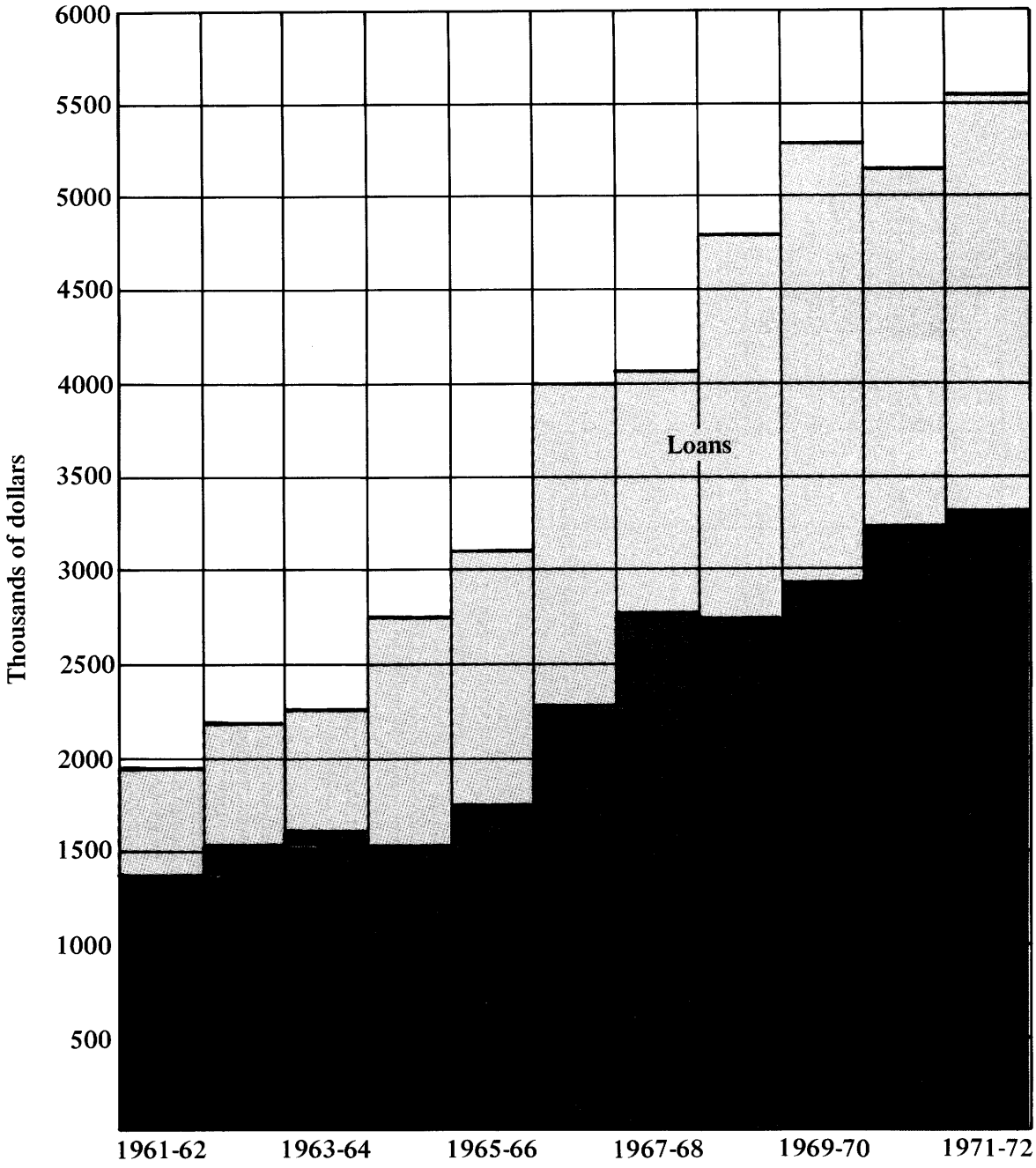


FIGURE 2

FINANCIAL AID TO GRADUATE STUDENTS
AWARDED BY M.I.T. 1962-1972

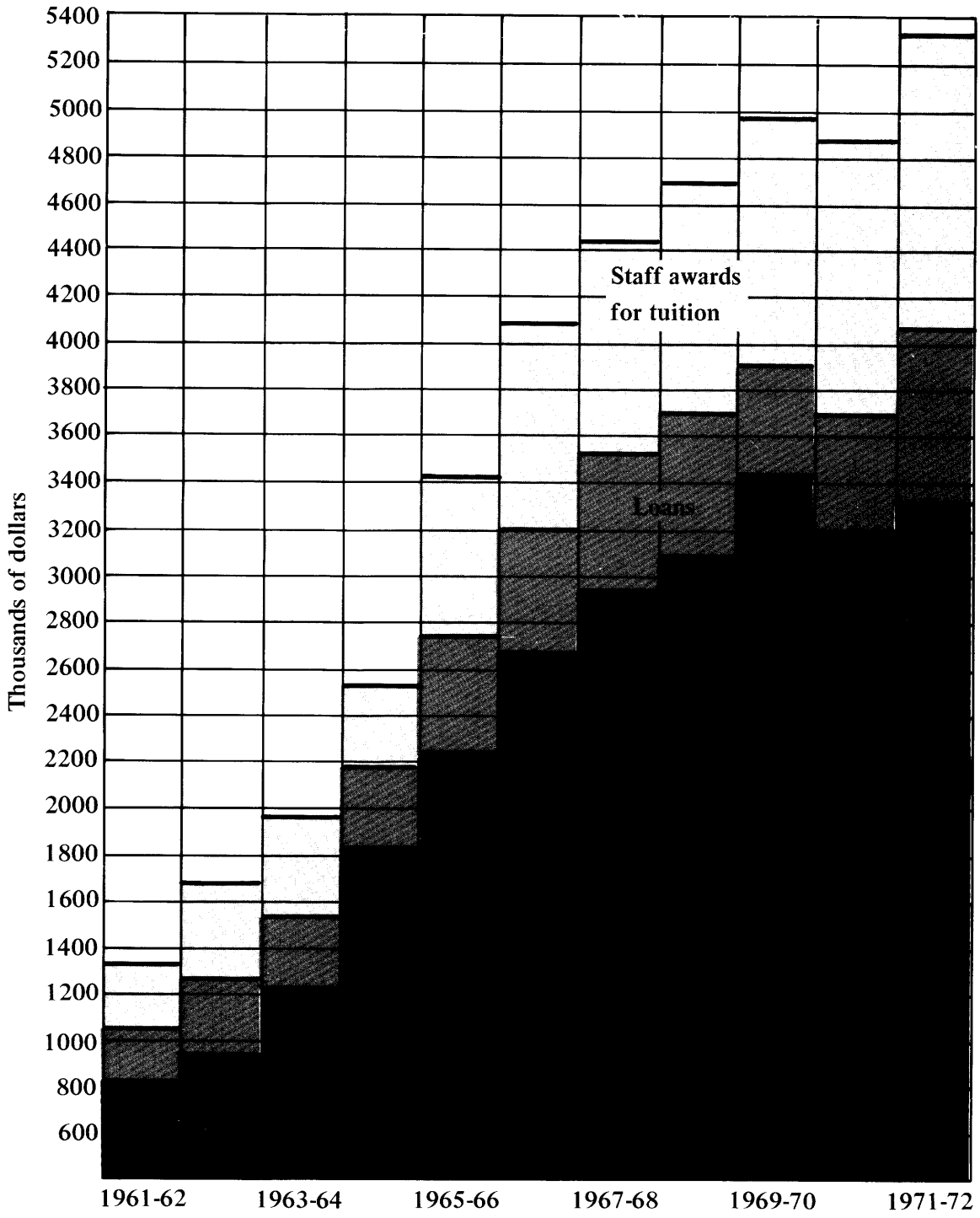
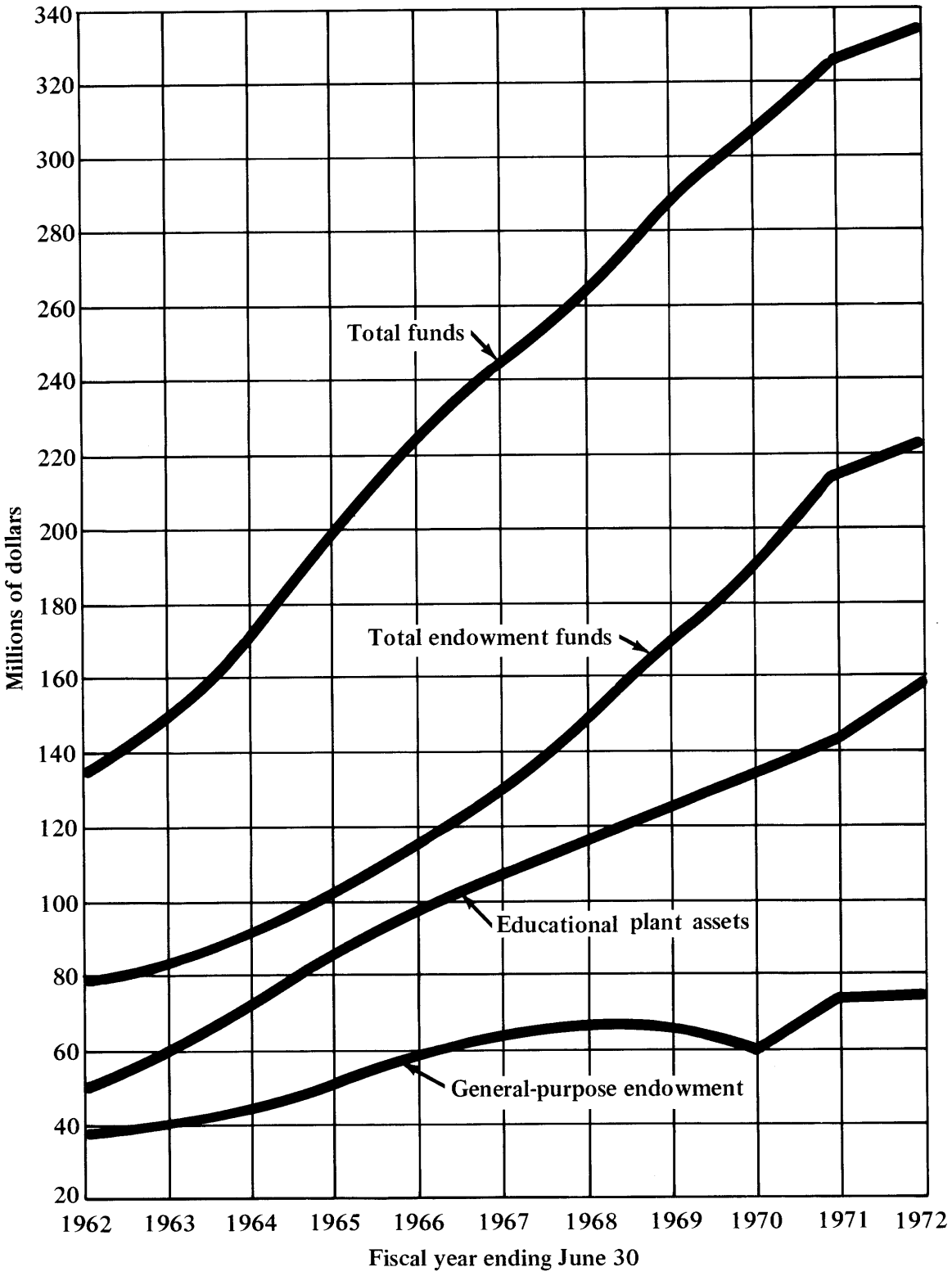


FIGURE 3
THE GROWTH OF M.I.T.'S FUNDS AND PLANT ASSETS, 1962-1972



M. I. T. also made $49,004 in loans to graduate students under this program. An additional $434,685 of National Defense Loan Fund was made available to graduate students this year. The total loaned by M. I. T. to 2,121 graduate and undergraduate students was $2,463,364, an increase of $335,137 over last year's total.

## Placement

The economic recession, the effects of which were first felt in the 1969-70 academic year, continued to leave its mark on the work of the Career Planning and Placement Office in 1971-72. The number of companies and government agencies coming to interview graduating students dropped by 17 per cent, following a drop of 24 per cent the previous year. It was again the case that most alumni registering with the Office were out of work or feared that they soon would be. Alumni registrants totaled 710 during the course of the year, which was a significant drop from the 972 who turned to the Office for help in 1970-71 but still a high figure.

Fortunately, the last months of the year brought signs of an upturn as a number of companies which had not expected to have vacancies to fill made last-minute arrangements to recruit. A reassuring number of students had problems choosing among job offers. Companies inquiring about starting salary rates reported that they were beginning to face competition for the candidates they wanted. The drop in alumni registrations also pointed to better times.

## Finances

As reported by the Treasurer, the total financial operations of the Institute, including sponsored research, increased beyond the level of 1970-71. Educational and general expenses— excluding the direct expenses of departmental and interdepartmental research, the Lincoln Laboratory, and the Charles Stark Draper Laboratory— amounted to $72,512,000 during 1971-72, compared to $71,945,000 in 1970-71. Reflected in the finances of the Institute was the decrease in the use of general purpose funds to $1,593,000, compared with $4,907,000 in the preceding year.

The direct expenses of general departmental and interdepartmental sponsored research increased from $49,015,000 to $56,467,000, and the direct expenses of major laboratories and special departmental research increased from $87,232,000 to $101,143,000.

The construction program of the Institute continued to make progress in 1971-72, with the book value of educational plant facilities increasing from $143,120,000 to $157,651,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, had a book value of $326,482,000 and a market value of $439,596,000. This compares to book and market totals of $316,176,000 and $395,428,000 last year.

Gifts, grants, and bequests to M. I. T. from private donors decreased from $39,637,000 for Fiscal Year 1970-71 to $22,049,000 for Fiscal Year 1971-72. The latter figure includes unrestricted direct gifts to the Alumni Fund of $813,000, which made up a part of the total of $2,792,000 reported by the Alumni Fund in 1971-72.

## Physical Plant and Campus Environment

The Burton-Conner undergraduate dormitory renovation was completed in the fall of 1971. The dormitory renovation took 14 months and involved a complete renewal of the building except for the masonry shell and the wood floors. Burton-Conner now houses 344 undergraduates in modern suite accommodations; this new style of residential living is the second facility of its type now in service on campus.

Construction of Westgate II, a high-rise residential facility on the west end of the campus,

continued during the year with occupancy scheduled for fall of 1972. Westgate II will house 401 single graduate students in one-, three-, and four-bedroom apartments.

The J. B. Carr Indoor Tennis Center on Briggs Field was completed in the fall of 1971. The Tennis Center is housed in an inflatable structure that accommodates four tennis courts.

Also completed in the fall of 1971 was the George R. Wallace, Jr., Astrophysical Observatory in Westford, Massachusetts. The Observatory, made possible by a gift from Mr. George R. Wallace, Jr., Class of 1913, houses 16-inch and 24-inch telescopes.

The James and Lynelle Holden Human Biology Teaching Laboratory has been established in Building 4 where extensive renovations are currently underway. These educational facilities in human biology represent a fundamental first step in the establishment of new health sciences education and research programs at M. I. T. The Laboratory, scheduled for completion in the coming year, will be used in conjunction with the joint Harvard-M. I. T. Program in Health Sciences and Technology.

Construction continued during the year on the Electrical Engineering and Communications Research Building. The structural frame was completed in May, 1972, and the date for total completion is now forecast as June, 1973.

The major additions to the Central Utilities Plant are nearing completion. This will be the culmination of a three-year program to add both steam boiler and chilled water capacity, as well as to extend the campus steam distribution system, to the new West Campus housing facilities.

In August, 1972, the electro-mechanical telephone switch which has provided telephone service to M. I. T. for 30 years was replaced by CENTREX (central exchange), an electronic switching system. The CENTREX system, involving 8,350 telephone extensions, will provide more efficient service by enabling outside callers to reach M. I. T. offices directly rather than through a switchboard.

New projects in the preliminary design stage or under consideration include a Chemical Engineering Building, to be located to the east of the Whitaker Building; renovation of Ashdown House; renovation of a section of the Ford Building for health-related research; and additional student housing on the West Campus.

# Personnel Changes from October 1, 1971, to September 30, 1972

## Corporation

DEATHS

Duncan R. Linsley
Life Member Emeritus

William Webster
Life Member

CHANGE OF APPOINTMENT

Thomas D. Cabot
Life Member Emeritus

ELECTIONS

W. Gerald Austen
Member

W. Van Alan Clark, Jr.
Member

Thomas J. Curtin
Commissioner of Education

Rebecca A. Donnellan
Representative from Recent Classes

W. H. Krome George
Member

J. Kenneth Jamieson
Member

Breene M. Kerr
President of Alumni Association

Paul V. Keyser
Member

Ralph Landau
Member

Clint W. Murchison, Jr.
Member

I. M. Pei
Member

H. I. Romnes
Member

Paul P. Shepherd
Member

## Faculty

RETIREMENTS

Joseph Bicknell
Professor of Aeronautics and Astronautics

Robley D. Evans
Professor of Physics

Harold W. Fairbairn
Professor of Geology

Everett E. Hagen
Professor of Economics and Political Science
Director of the Center for International Studies

Gyorgy Kepes
Institute Professor
Professor of Visual Design

Deane Lent
Professor in Mechanical Engineering

Klaus Liepmann
Professor of Music
Director of Music

Walter McKay
Professor of Aeronautics and Astronautics

Herbert H. Uhlig
Professor of Metallurgy

Robert S. Woodbury
Professor of the History of Technology

RESIGNATIONS

Professors:

Jack E. Baldwin
Chemistry

F. Albert Cotton
Chemistry

Icko Iben
Physics

Associate Professors:

Thomas A. Belote
Physics

Richard J. Briggs
Electrical Engineering

Charles T. Cole
Humanities

Wallace B. S. Crowston
Sloan School of Management

Robert Goodman
Architecture

Robert M. Graham
Electrical Engineering

Ronald C. Hirschfeld
Civil Engineering

Rosalind E. Krauss
Architecture

W. Stephen Lewellen
Aeronautics and Astronautics

Chung L. Liu
Electrical Engineering

William R. Moore
Chemistry

James P. Moran
Aeronautics and Astronautics

Donald E. Nelsen
Electrical Engineering

John S. Saloma, III
Political Science

Gustav Schonfeld
Nutrition and Food Science

Vigdor L. Teplitz
Physics

Preetinder S. Virk
Chemical Engineering

Assistant Professors:

Hans D. Betz
Physics

Christopher Boehm
Humanities

Roland Davies
Nutrition and Food Science

John T. Day
Chemical Engineering

Matthew D. Edel
Economics

Peter H. Elbow
Humanities

Jackson A. Giddens
Political Science

Ronald E. Grieson
Economics

Robert E. Herzstein
Humanities

Paul W. Hoff
Electrical Engineering

Samson T. Jacob
Nutrition and Food Science

Milton L. Lavin
Sloan School of Management

Amos Levin
Aeronautics and Astronautics

David M. Levin
Philosophy

Geoffrey Margolis
Chemical Engineering

Dennis L. Meadows
Sloan School of Management

Mark F. Nelson
Civil Engineering

Patrick E. O'Neil
Electrical Engineering

Alan L. Patz
Sloan School of Management

Anand Prakash
Physics

David J. Sellmyer
Metallurgy and Materials Science

Christopher R. Sprague
Sloan School of Management

Ronald A. Walter
Urban Studies and Planning

Kang-Lung Wang
Electrical Engineering

PROMOTIONS

To Professor:

Stanford O. Anderson
Architecture

David Baltimore
Biology

Emilio Bizzi
Psychology

Hale Bradt
Physics

Roger G. Burns
Earth and Planetary Sciences

Richard M. Dudley
Mathematics

Albert R. Gurney, Jr.
Humanities

Alan Hein
Psychology

Roy Kaplow
Metallurgy and Materials Science

Padmakar P. Lele
Mechanical Engineering

Jean F. Louis
Aeronautics and Astronautics

Marvin L. Manheim
Civil Engineering

Fred Moavenzadeh
Civil Engineering

William T. Peake
Electrical Engineering

Whitman A. Richards
Psychology

Robert M. Rose
Metallurgy and Materials Science

Adel F. Sarofim
Chemical Engineering

Ethan R. Signer
Biology

Harold M. Stark
Mathematics

Robert E. Stickney
Mechanical Engineering

August F. Witt
Metallurgy and Materials Science

Theodore Wood, Jr.
Humanities

To Associate Professor:

Edward B. Allen
Architecture

Jonathan Allen
Electrical Engineering

Robert C. Beardsley
Meteorology

John L. Buttrick
Humanities

Diane S. Clemens
Humanities

Eric R. Cosman
Physics

Robert W. Crandall
Economics

Martin Diskin
Humanities

Gerald B. Dworkin
Philosophy

Shaoul Ezekiel
Aeronautics and Astronautics

George F. Farris
Sloan School of Management

Nazli C. Field
Political Science

Frederick A. Frey
Earth and Planetary Sciences

John Harbison
Humanities

William L. Henke
Electrical Engineering

Jack B. Howard
Chemical Engineering

Roman W. Jackiw
Physics

Keith H. Johnson
Metallurgy and Materials Science

Richard C. Larson
Urban Studies and Planning

John S. Lewis
Earth and Planetary Sciences

David C. Major
Civil Engineering

Alaa E. Mansour
Ocean Engineering

Roger G. Mark
Electrical Engineering

David H. Marks
Civil Engineering

William A. Martin
Sloan School of Management

Albert R. Meyer
Electrical Engineering

D. Quinn Mills
Sloan School of Management

John W. Negele
Physics

Nicholas P. Negroponte
Architecture

Edward Pincus
Architecture

Richard F. Salant
Mechanical Engineering

Myron S. Scholes
Sloan School of Management

David J. Sellmyer
Metallurgy and Materials Science

To Assistant Professor:

Christopher Boehm
Humanities

Susan Carey-Block
Psychology

Lloyd A. Clomburg, Jr.
Chemical Engineering

Patricia Cumming
Humanities

John T. Day
Chemical Engineering

Michael B. Folsom
Humanities

Charles T. Grant
Physics

Douglas A. Hibbs
Political Science

James L. Kirtley, Jr.
Electrical Engineering

Joseph B. Lassiter, III
Ocean Engineering

Alan Needleman
Mathematics

Richard S. Sidell
Mechanical Engineering

CHANGES OF APPOINTMENT

Michael C. Archer
Assistant Professor in Nutrition and Food Science

Floyd O. Arntz
Lecturer in Electrical Engineering

Lotte Bailyn
Associate Professor in the Sloan School of Management

Floyd B. Barbour
Assistant Professor in Humanities

Murray J.K. Biggs
Assistant Professor in Humanities

Samuel W. Bodman
Lecturer in Chemical Engineering

Myra Brenner
Assistant Professor in Humanities

Wilbur B. Davenport, Jr.
Professor of Engineering and Director, Center for Advanced Engineering Study

Evsey D. Domar
Ford Professor in Economics

Richard G. Donnelly
Assistant Professor in Chemical Engineering

Jay W. Forrester
Germeshausen Professor in Sloan School of Management

Devendra P. Garg
Lecturer in Mechanical Engineering

Edwin R. Gilliland
Institute Professor and Warren K. Lewis Professor of Chemical Engineering

Michael B. Godfrey
Visiting Assistant Professor in Civil Engineering

Samuel A. Goldblith
Underwood-Prescott Professor of Food Science and Deputy Department Head in Nutrition and Food Science

William E. Griffith
Ford Professor in Political Science

Paul R. Gross
Visiting Professor in Biology

Brendan M. Harley
Research Affiliate in Civil Engineering

Hans H. Harms
Lecturer in Architecture

Andrew R. Hawley
Research Affiliate in Humanities

J. Herbert Hollomon
Visiting Professor of Engineering and Director, Center for Policy Alternatives

Robert W. Hopper
Assistant Professor in Metallurgy and Materials Science

Estil V. Hoversten
Visiting Associate Professor in Electrical Engineering

Phillip Issenberg
Research Associate in Nutrition and Food Science

Moshe Israeli
Assistant Professor in Meteorology

Charles E. Kimble
Assistant Professor in Nutrition and Food Science

Charles P. Kindleberger
Ford Professor in Economics

Susan G. Kleinmann
Assistant Professor in Physics

Karl Linn
Visiting Associate Professor in Urban Studies and Planning

William B. Lenoir
Research Affiliate in Research Laboratory of Electronics

Joan E. Lusk
Visiting Assistant Professor in Biology

Loy D. Lytle
Assistant Professor in Nutrition and Food Science

Henry S. Marcus
Assistant Professor in Ocean Engineering

Donald G. Marquis
David Sarnoff Professor in the Sloan School of Management

Samuel J. Mason
Cecil H. Green Professor in Electrical Engineering and Associate Director, Research Laboratory of Electronics

James H. Porter
Associate Professor in Chemical Engineering

Anand Prakash
Assistant Professor in Physics

Lucian W. Pye
Ford Professor in Political Science

John W. Reed
Visiting Assistant Professor in Civil Engineering

Richard D. Robinson
Professor in Sloan School of Management

Ignacio Rodriguez-Iturbe
Associate Professor in Civil Engineering

Irwin M. Rubin
Lecturer in Sloan School of Management

Richard F. Salant
Lecturer in Mechanical Engineering

Donald A. Schon
Ford Professor in Urban Studies and Planning

William G. Thilly
Assistant Professor in Nutrition and Food Science

Annamaria Torriani-Gorini
Associate Professor in Biology

Arthur P. L. Turner
du Pont Assistant Professor
in Mechanical Engineering

Sean Wellesley-Miller
Visiting Assistant Professor
in Architecture

James H. Williams, Jr.
du Pont Assistant Professor
in Mechanical Engineering

Anwar E. Z. Wissa
Research Associate in
Civil Engineering

NEW FACULTY
APPOINTMENTS

Professors:

Elting E. Morison
Elizabeth and James Killian
1926 Professor in the School of
Humanities and Social Science

Paul O. Roberts
Civil Engineering

Associate Professors:

William A. Davis, Jr.
Urban Studies and Planning

Malcolm L. Gefter
Biology

Bennett Harrison
Urban Studies and Planning

Arnoldo C. Hax
Sloan School of Management

Mary Lou Pardue
Biology

Karen R. Polenske
Urban Studies and Planning

Ernesto Pollitt
Nutrition and Food Science

John G. Sclater
Earth and Planetary Sciences

Martin L. Weitzman
Economics

Assistant Professors:

Carl S. Apstein
Nutrition and Food Science
and Assistant Director of
the Clinical Research
Center

Martin N. Baily
Economics

Kenneth Brecher
Physics

Bruce S. Buckley
Mechanical Engineering

Ian F. Davenport
Chemical Engineering

Carleton E. De Tar
Physics

John S. Dickey, Jr.
Earth and Planetary Sciences

Charles H. Dowding
Civil Engineering

Rufus E. Hallmark, Jr.
Humanities

Hugh H. Heclo
Political Science

Ronald A. Hites
Chemical Engineering

Nancy J. Hoffman
Humanities

Jean E. Jackson
Humanities

Timothy L. Johnson
Electrical Engineering

Paul L. Joskow
Economics

Barbara H. Liskov
Electrical Engineering

Stuart E. Madnick
Sloan School of Management

June L. Matthews
Physics

Stephen F. Moore
Civil Engineering

John W. Morgan
Mathematics

Charles M. Oman
Aeronautics and Astronautics

Vaughn R. Pratt
Electrical Engineering

Stephen A. Raymond
Biology

David W. Smith
Philosophy

Joel H. Spencer
Mathematics

Ian D. Terner
Urban Studies and Planning

Jefferson W. Tester
Chemical Engineering

John E. Van Maanen
Sloan School of Management

Christopher T. Walsh
Chemistry

William C. Wheaton
Economics
Urban Studies and Planning

Thomas R. Willemain
Urban Studies and Planning

Mark S. Wrighton
Chemistry

Robert K. Yin
Urban Studies and Planning

VISITING FACULTY

Visiting Professors:

Eric Baer
Metallurgy and Materials
Science

Zeki Berk
Nutrition and Food Science

Donald R. Blumberg
Architecture

Herbert J. Carlin
Electrical Engineering

Llayron L. Clarkson
Mathematics

Charles T. Cole
Humanities

Esther M. Conwell
Abby Rockefeller Mauze
Visiting Professor in
Electrical Engineering

Dean E. Eastman
Electrical Engineering

Joe F. Elliott
Military Science and Director,
Office of Military Science

Ann F. Friedlaender
Economics

Peter Hammann
Sloan School of Management

Ruth Hubbard
Biology

Ram Karmi
Bemis Visiting Professor
in Architecture

Charles J. Kensler
Nutrition and Food Science

Jean P. Leinroth, Jr.
Chemical Engineering

Cecil E. Leith
Meteorology

Detlef Marx
Economics

John McCarthy
Electrical Engineering

Barrett O'Neill
Mathematics

Michael O. Rabin
Mathematics

Laura M. Roth
Abby Rockefeller Mauze
Visiting Professor in
Physics

J. Clifton Samuels
Electrical Engineering

Philip E. Sarachik
Electrical Engineering

G. Dale Sheckels
Electrical Engineering

Louis G. Stolzenberg
Mathematics

Peter H. Stone
Meteorology

Robert S. Stone
Sloan School of Management

Thirukodikaval Srinivasan
Economics

Avraham Wachman
Bemis Visiting Professor
in Architecture

John R. Wiley
Aeronautics and Astronautics

E-An Zen
Crosby Visiting Professor
in Earth and Planetary
Sciences

Visiting Associate Professors:

Hubertus Adebahr
Sloan School of Management

Jay M. Anderson
Sloan School of Management

James W. Beatty, Jr.
Chemistry

Colin B. Blakemore
Psychology

Gregory D. Botsaris
Chemical Engineering

Arnon Dar
Physics

Eckehard V. Dehmlow
Chemistry

Jerry D. Dermer
Sloan School of Management

Paul Earls
Humanities

Wesley L. Harris, Sr.
Aeronautics and Astronautics

Lauri J. Karttunen
Foreign Literatures and
Linguistics

Kjell Kleppe
Biology

Dieter List
Nutrition and Food Science

David R. Miller
Mechanical Engineering

Olaf H. Peters
Aeronautics and Astronautics

D. Vincent Roach
Aeronautics and Astronautics

Dewey D.Y. Ryu
Nutrition and Food Science
Chemical Engineering

David Schieber
Electrical Engineering

Robert M. Stark
Civil Engineering

Ronald W. Wolff
Sloan School of Management

Ray J. Wu
Biology

Peter Zimmermann
Physics

Visiting Assistant Professors:

Robert F. Beck
Ocean Engineering

Min Chen
Physics

Nathan Gartner
Civil Engineering

Gunter Waas
Civil Engineering

Award:
Nevin S. Scrimshaw
Killian Award Lecturer for the Academic Year 1972-73

## Administration

RETIREMENTS

Jerome H. Barraford
Superintendent of Power and Utilities
Physical Plant

Richard E. Collins
Technical Assistant
Physical Plant

Frank H. Conant
Director
Graphic Arts

Carl M.F. Peterson
Director
Physical Plant

Albert F. Sise
Associate Director
Office of Personnel Relations

Arthur B. White
Manager
Office of Laboratory Supplies

Evelyn B. Yates
Associate Director and Alumni Placement Officer
Career Planning and Placement Office

RESIGNATIONS

Dwight E. Agner
Production Manager
M.I.T. Press

Janet B. Arterton
Community Development Assistant
Planning Office

Penny M. Bowman
Programmer
Office of Administrative Information Systems

David S. Cohen
Investment Accountant
Comptroller's Accounting Office

Daniel F. Creasey
Associate
Analytical Studies Group

Ralph J. Devir, Jr.
Project Manager
Institute Real Estate Office

Max William Dix, Jr.
Assistant Director of Admissions
Executive Director of the Educational Council

Richard P. Dober
Director of Long Range Planning
Planning Office

Mary S. Doebele
Senior Community Planner
Planning Office

Gregory H. Dunham
Personnel Counselor
Office of Personnel Relations

Vincent L. Foxworthy
Senior Systems Programmer
Office of Administrative Information Systems

Mary M. Furey
Systems Analyst
Office of Administrative Information Systems

John C. Ginn
Administrative Staff
News Office

Edward W. Haas
Financial Director
M.I.T. Press

Alan E. Hagyard
Programmer
Office of Administrative Information Systems

Jay C. Hammerness
Special Assistant
Career Planning and Placement Office

Antony L. Herrey
Director
Institute Real Estate Office

David Hodgdon
Architect/Programmer
Planning Office

Lawrence A. Hough
Assistant Director of Student Financial Aid

Richard F. Hughes
Professional Personnel Officer
Office of Personnel Relations

Gordon F. Jones
Supervisor of Employee Training
Office of Personnel Relations

George J. La Breche, Jr.
Assistant to the Dean for Student Affairs

John A. Langell
Project Programmer
Planning Office

Kasha Linville
Director of Exhibitions
Committee on the Visual Arts

Edward G. Marcato
Assistant to the Director
Division of Sponsored Research

Amy J. Metcalfe
Administrative Assistant
Vice President for Research

Douglas G. Miller
Assistant to the Director
Division of Sponsored Research

Maxine D. Moffett
Basic Education Instructor
Office of Personnel Relations

Harry C. Moser
Assistant Director
Industrial Liaison Office

Raymond S. O'Connor
Associate Auditor
Audit Division

Dorothy B. Owusu
Assistant to the Dean
of the Graduate School

Horace S. Palmer
Superintendent of Mechanical
Services
Physical Plant

John G.N. Rushbrook
Assistant News Director
Institute Information Services

Kenneth E. Schoman, Jr.
Special Assistant to the
Chancellor
Office of the President
and Chancellor

John J. Silvasy
Assistant Auditor
Audit Division

Nanette L. Smith
Assistant Dean for Student
Affairs

John S. Snyder, Jr.
Senior Acquisitions Editor
(Applied Science)
M.I.T. Press

India S. Thompson
Personnel Representative
Office of Personnel Relations

Emily L. Wick
Associate Dean for Student
Affairs

David Waite Yohn
Assistant Dean for Student
Affairs

## APPOINTMENTS AND CHANGES

Edward Agro
Senior Editor
M.I.T. Press

James C. Allison, Jr.
Assistant for Minority
Affairs
Office of the President
and Chancellor

Matthew J. Arno
Staff Accountant
Draper Laboratory Fiscal
Office

Paul F. Barrett
Superintendent for
Engineering and
Construction
Physical Plant

Frederick C. Bentley II
Assistant Director
Division of Sponsored
Research

Irving A. Berstein
Assistant Director for
Research
Program Development
Harvard-M.I.T. Program in
Health Sciences and
Technology

Donald L.M. Blackmer
Executive Officer and
Associate Professor in
Political Science

Leslie M. Boring, Jr.
Special Assistant to the
Vice President and Secretary
of the Institute and to the Head
of the Department of
Chemical Engineering

Pauline J. Boulard
Assistant Accounting Officer
for Benefits
Comptroller's Accounting Office

James F. Brady
Accounting Officer for
Cash Receipts
Comptroller's Accounting Office

Harmon E. Brammer
Director
Housing and Food Services

Kenneth C. Browning
Assistant Dean for Student
Affairs

Joseph J. Casarano, Jr.
Assistant Auditor
Audit Division

Harold F. Chevalier
Assistant Director
M.I.T. Press

Jack W. Christensen
Secretary
M.I.T. Development
Foundation, Inc.

Gerald L. Clarke
Manager of Technical Services
Office of Administrative
Information Systems

William J. Coady
Assistant Auditor
Audit Division

William H. Combs
Superintendent of Buildings
Physical Plant

Laurence J. Connelly, Jr.
Accounts Payable Supervisor
Comptroller's Accounting Office

Joseph F. Connolly
Assistant Director
Division of Sponsored Research

James E. Conway
Programmer
Office of Administrative
Information Systems

Miles P. Cowen
Assistant Director for Special Services
Physical Plant

Frederick I. Crowley
Staff Accountant
Comptroller's Accounting Office

John A. Currie
Assistant Comptroller
Office of the Comptroller

Kreon L. Cyros
Associate Director
Administration and Systems Planning Office

Robert C. Daley
Director of the Programming Development Office
Assistant Director of Information Processing Services

Robert M. Dankese
Assistant Director
Fiscal Planning and Budget Office

Theodore M. Doan, Jr.
Manager of Building Services
Physical Plant

Thomas E. Donnelly
Project Director, Planning Systems
Planning Office

Mildred S. Dresselhaus
Associate Head for Electrical Science and Engineering and Professor in Electrical Engineering

William J. Duggan
Assistant Director for Business Operations
The Libraries

Ira Dyer
Head of Department of Ocean Engineering and Professor in Ocean Engineering

Carola B. Eisenberg
Dean for Student Affairs

Anne Ellison
Assistant Dean for Student Affairs

John O. Flender
Staff
M. I. T. Development Foundation, Inc.

Carl F. Floe
Professor and Acting Head of Department of Metallurgy and Materials Science

Haig G. Gechijian
Deputy Superintendent of Buildings
Physical Plant

Ruth S. Goodwin
Administrative Assistant
Office of the Registrar

Susan P. Haigh
Advisor on Preprofessional Education
Office of the President and Chancellor

J. Bradford Haley
Assistant to the Director
Office of Student Financial Aid

Harold J. Hanham
Dean of the School of Humanities and Social Science

Sheila M. Hayes
Accounts Receivable Supervisor
Comptroller's Accounting Office

Richard M. Held
Professor and Acting Head of the Department of Psychology

David H. Henshaw
Staff Accountant
Comptroller's Accounting Office

Anne S. Hirsch
Industrial Liaison Officer

Sandra J. Holland
Personnel Assistant
Office of Personnel Relations

Josef F. Jacquart
Operations Control Supervisor
Office of Administrative Information Systems

Francis S. Jannetti
Accounts Receivable Representative
Comptroller's Accounting Office

Dennis C. Jedlinsky
Industrial Liaison Officer

Barbara A. Johnson
Administrative Assistant
Office of the Vice President for Research

Charles R. Johnson
Project Manager
Physical Plant

William E. Kelley
Assistant Comptroller
Fiscal Planning and Budget Office

Kenneth E. Kempson
Systems Analyst
Office of Administrative Information Systems

Charles F. Kiefer, Jr.
Assistant Director
Division of Sponsored Research

Karalyn Krasin
Administrative Assistant
Dean of the School of Architecture and Planning

Dorothy R. Latsey
Assistant Student Loan Officer
Comptroller's Accounting Office

John S. Lavalle
Accounting Officer for Contracts, Funds, and Grants
Comptroller's Accounting Office

Henry J. Leonard
Superintendent for Support Services
Physical Plant

Barbara K. Levey
Acquisitions Editor
M.I.T. Press

Kenneth F. Levie
Financial Manager
M.I.T. Press

William N. Locke
Foreign Study Advisor and Professor in Foreign Literatures and Linguistics

Thomas E. Lightburn, Jr.
Assistant to the Director
Division of Sponsored Research

James L. Maclary
Accounting Officer for Budgets
Fiscal Planning and Budget Office

Lawrence E. Maguire
Assistant Director of Student Financial Aid

Richard V. McDevitt
Assistant to the Director
Fiscal Planning and Budget Office

Daniel J. McDonald
Systems Analyst
Office of Administrative Information Systems

Lawrence W. McKinnon
Grants and Contracts Accountant
Comptroller's Accounting Office

Jeanne M. McLeod
Staff Accountant
Draper Laboratory Fiscal Office

Howard Miller
Assistant to the Director
Physical Plant

Walter L. Milne
Special Assistant to the President for Urban Relations and Assistant to the Chairman of the Corporation

Jean E. Morin
Administrative Assistant
Education Research Center

Peggy J. Murrell
Associate
Analytical Studies Group

Barbara S. Nelson
Assistant to the President and Chancellor
Office of the President and Chancellor

Natalie N. Nicholson
Acting Director of Libraries

J. Daniel Nyhart
Special Assistant to the Chancellor
Office of the President and Chancellor

John D. O'Connor
Staff Accountant
Comptroller's Accounting Office

Albert K. Paone
Production Manager
Graphic Arts

Joseph M. Patten
Assistant Director of Information Processing Services and Director of the Office of Administrative Information Systems

Marc J. Pokempner
Photojournalist in the News Office
Institute Information Services

Paul C. Powell
Assistant to the Director
Fiscal Planning and Budget Office

Ronald W. Regan
Staff Accountant
Lincoln Laboratory Fiscal Office

Peter H. Richardson
Director of Admissions
Admissions Office

Richard O. Sales
Assistant Media/Production Manager
M.I.T. Press

Barbara J. Saulenas
Order Fulfillment Manager
M.I.T. Press

Jerome J. Schaufeld
Director
M.I.T. Associates Office

John C. Sears
Senior Accounting Officer
Comptroller's Accounting Office

Alice M. Seelinger
Administrative Officer
Office of the Dean for Student Affairs

Michael Seif
Assistant Director
News Office
Institute Information Services

Charles J. Sheehan
Director
Industrial Liaison Office

Thomas E. Shepherd, Jr.
Superintendent of Utilities
Physical Plant

Eugene B. Skolnikoff
Professor and Head of the Department of Political Science and Director, Center for International Studies

John Stavropoulos
Programmer
Office of Administrative Information Systems

Roberta O. Stearns
Assistant to the Director
Division of Sponsored Research

Frank R. Stevens
Director
Fiscal Planning and Budget Office

James F. Steuert
Programmer
Office of Administrative Information Systems

Robert M. Sullivan
Staff Accountant
Comptroller's Accounting Office

William J. Sweeney, Jr.
Project Manager
Institute Real Estate Office

Paul K. Tamulynas
Grants and Contracts Accountant
Comptroller's Accounting Office

Walt C. Taylor
Curator of Historical Collection
Committee for Institute Memorabilia

David J. Tobin
Special Assistant
Office of Vice President and Secretary

Ruth E. Walsh
Interdepartmental Transfers Supervisor
Comptroller's Accounting Office

Nancy J. Wheatley
Assistant to the Dean for Student Affairs

Clarence G. Williams
Assistant Dean of the Graduate School

# Provost

## Artificial Intelligence Laboratory

During FY 1972, the Artificial Intelligence (A.I.) Laboratory increased its level of education research under Professor Seymour A. Papert's direction. There were eight staff members, five graduate students, and five undergraduates involved in this effort. This project, which is studying new ideas about how people develop cognitive skills, seems likely to contribute significantly to educational philosophy, as well as provide new opportunities to study human cognitive development. Studies in human intellectual development greatly influence this laboratory's main research effort in further developing machine intelligence.

Professors Marvin L. Minsky and Seymour A. Papert directed the general studies in artificial intelligence which include natural and artificial language projects by Richard D. Greenblatt and Professors Terry A. Winograd and Carl E. Hewitt and a Machine Vision project by Professor Patrick H. Winston. Professor Michael J. Fischer participated in automata theory studies with Professors Edwin W. Meyer and Frederick C. Hennie of Project MAC.

Additional funding was obtained this year to develop a "Mini-Robot," a small-scale robotics laboratory intended for use by workers interested in pursuing research on automation (primarily automatic assembly) or more advanced research and development in robotics without the usual large investment required to start an artificial intelligence research project. This "Mini-Robot" project will be supervised by Dr. Berthold K. P. Horn and Professor Patrick H. Winston.

Richard Greenblatt continues directing support and development of his "I. T. S." Artificial Intelligence Laboratory Time Sharing System under which Project MAC's MATHLAB and Dynamic Modeling computers now also operate. Project MAC acquired a separate PDP-10 computer system for Professors Moses' and Martin's MATHLAB project. Transferring MATHLAB to that machine removed a large computation load from the A.I. time sharing system, thereby allowing postponement of major system capacity expansion until a more powerful processor becomes available.

Fifty-three faculty, staff, and graduate students were employed in research which was funded at $1,666,500 for FY 1972, up $554,300 from FY 1971. Seventeen undergraduates were included in our total of 81 Laboratory employees.

MARVIN L. MINSKY

## Cambridge Electron Accelerator

The Cambridge Electron Accelerator Laboratory is engaged in an exciting development of changing the accelerator into a colliding beam system. Counter-traveling beams of electrons and positrons are accelerated each to energies up to 3.5 GeV, stored in the accelerator and then switched through a bypass where they are made to collide headon. As the result of several successful new developments in accelerator physics, the number of collisions between 2-GeV electrons and 2-GeV positrons had reached a sufficient number to start the experimental program in May, 1972. The experiments are designed to study the basic electromagnetic interaction at smaller distances than has been possible before, and to explore the forces between photons and elementary particles in a new higher energy region.

KARL STRAUCH

## Cambridge Project

The goal of the Cambridge Project is to make computers more useful in the behavioral sciences. The participants are behavioral and computer scientists, both from Harvard University and from M.I.T. During the past year about 40 members of the faculties of the two universities served on planning committees or took responsibility for parts of the Project's work.

At present, the work has two main parts. One is the development of computing tools that are needed in behavioral science -- tools for managing data, for analyzing data, for building and verifying models, and for running experiments in the laboratory. Most of these tools are programs, but a few of them are data or even combinations of programs and equipment. They are described at length in the Project's Annual Report.

The other part of the work is assembling a Consistent System of programs, models, and data that will serve many of the behavioral sciences. It is designed to be used on line and is at present based on the Multics time-sharing system. The programs and data are to be, as much as possible, compatible enough so that the user can combine them, in whatever way his research problem seems to dictate, without the help of a programmer.

During the past year the framework for the system was established which was an important step. It determined the nature of the system in many ways that were in practice irrevocable, and it was therefore preceded by much careful planning and by an exploratory system called "Toss." The framework consists of: a Substrate, which is a group of routines on which the programs in the collection depend for all communication with each other and with Multics; conventions, including conventions about documentation, that the programs are required to follow; and rudimentary procedures for accepting contributions to the collection, for managing changes, and in general, for controlling what may become a considerable mass of programs and data. With the framework established, the collection began to accumulate. At present it is growing rapidly as programs that have been developed in the other part of the Project's work are added to it.

DOUWE B. YNTEMA

## Center for Advanced Visual Studies

The past year was the fifth year of the Center's existence. The various creative explorations initiated in the previous years came for the first time into clear and convincing focus. The reason for this success was threefold. First, due to a generous grant from the Samuel H. Kress Foundation, supplemented by a grant from the National Endowment for the Arts, the Center experienced its first year without serious immediate budget difficulties. The Center received $100,000 from the Kress Foundation, $50,000 of which was designated for this academic year and $50,000 for the 1972-73 academic year. The $50,000 grant for this year received a matching fund from the National Endowment for the Arts. The second reason for our successful year was that after long experimentation with the selection of fellows, the Center shifted its emphasis and chose a combination of mature artists of international reputation, as well as younger, perhaps lesser known, figures. The proportions were apparently correct and the interaction between various activities was more successful than in previous years. Another reason for the more convincing achievement was that the major effort centered on large-scale collaborative projects with realistic foundations; consequently, the Center had the opportunity not only to explore on an abstract, ideal level, but to focus on concrete particulars as well.

The major collaborative effort, the Charles River Project, involved all members of the

Center, including a number of students from Urban Studies and Planning, Architecture, and other departments of the Institute. This project explored artistic possibilities which could re-establish the enhancing role of the river in the life of an urban community, specifically, the Charles River in metropolitan Boston. This collaborative work had three aspects: 1) combining needed water pollution abatement measures with artistic shaping of public spaces, which, in concrete terms, implied the synchronization of water purification equipment and hydraulic sculptural forms that could serve both as functional devices and aesthetic symbols for the city; 2) organizing educational events on an outdoor environmental scale which would bring ecological and social data on the river, as well as artistic experiences, into harmonious focus; and 3) planning for a recreational strip running on both sides of the river from Watertown Dam to the Science Museum, again combining aesthetic solutions with social, ecological, and educational overtones. In addition to this large-scale projected transformation of the interfacing of the river and the city, there were smaller scale projects aiming at the enrichment of neighborhoods with hydraulic sculptures and shaped land forms that could become important links between closed, high-density areas and the open expanse of the river. The Center received both encouragement and valuable technical help from Commissioner Sears and his staff in this task of revitalizing the role of the river in an urban setting.

Complementing this major project was an educational project whose purpose was to increase civic awareness of the problems related to the river's life and urban life. With the financial assistance of the Massachusetts Council on the Arts, the Center began preparation of an outdoor educational performance that would utilize a variety of visual communication devices in one or two evening performances, presenting various aspects of the river's life, its geological and social history, its present state (with both its negative and positive aspects), and suggestions for richer and more valid resolutions. The participants in this educational project included fellows, research affiliates, and students from various M.I.T. departments.

Another major cooperative project was the creation of an art exhibition for the blind at the Wadsworth Atheneum in Hartford, Connecticut. This exhibition, entitled "Dialogue for the Senses," aimed at stimulating both the unsighted and sighted into discovering their unexplored range of sense responses and appealed to all non-visual (tactile, acoustic, thermal, kinesthetic) senses in various forms of interaction. Almost all the fellows, as well as research affiliates and a number of students from the Department of Electrical Engineering and the School of Architecture and Planning, worked together to create this exhibition.

The final collaborative project was the designing and realization of a comprehensive exhibition of work done at the Center by present and former fellows Juan Navarro Baldeweg, Mauricio Bueno, Lowry Burgess, Paul Earls, John Goodyear, Michio Ihara, Gyorgy Kepes, Ted Kraynik, Alejandro Otero, Otto Piene, Stanley Resnicoff, Alan Sonfist, Wen Ying Tsai, Stanley Vanderbeek, Takis, and Friedrich St. Florian, who is the project coordinator. The exhibition is sponsored by three museums with the help of a matching grant of $45,000 from the National Endowment for the Arts. The exhibition will be interdisciplinary in nature, combining artistic creativity and technical and scientific competence.

In addition to these various collaborative ventures, the artists of the Center carried out their personal creative activities and received considerable public response. Two top awards were granted to members of the Center at the recent Bienal Coltejer III, a major international art exhibition held every two years in Colombia. The award winners were Professor Gyorgy Kepes and Mauricio Bueno. Professor Kepes' award was significant because it was realized as a result of collaboration between William U. Walton of the M.I.T. Department of Physics; Paul Earls, a fellow at the Center; and Mauricio Bueno, a fellow at the Center. In addition to Professor Kepes' and Mr. Bueno's entries, the works by fellows Ted Kraynik, Friedrich St. Florian, Alan Sonfist, and John Goodyear were also selected for exhibition at the Bienal Coltejer III.

The Center also initiated three forums under the general title, "Art and Environment" to encourage artists, scientists, architects, and urban planners to explore new artistic objectives of a civic nature, requiring a combination of technological knowledge and artistic creativity. Among the participants in the symposium, in addition to the Director and a number of fellows from the Center, were Isamu Noguchi, sculptor; Rudolf Arnheim, Professor of Psychology at Harvard University; Charles W. Moore, former Dean of the School of Architecture at Yale University; John Burchard, Dean Emeritus of the School of Humanities and Social Science; Provost Walter Rosenblith; Dean William Porter; and Dr. Carpenter, anthropologist from Toronto.

The Center's ideas and activities received international response, indicated by the numerous publications in foreign countries on the work of the Center or the work of the individual fellows, including articles published in the Boston Sunday Globe, The New York Times, L'Espresso, and The New Scientist by Jasia Reichardt. Another indication of the increasing acceptance of the Center's ideas was that the Center's announcement to accept a limited number of new fellows brought in over 350 applications.

The past year demonstrated that the Center has at least temporarily found both a relatively stable financial situation and work pattern that promises to be increasingly effective, both in producing significant artistic work as well as greater interaction with the M.I.T. community. Our hope is to expand our link both with the M.I.T. faculty and students whose interest, resources, and competence could amplify our own goals and resources and search for connections with various civic or public agencies and thus allow us to realize some of our projects in concrete form. To implement this hope, the Center is preparing projects for the next academic year that will involve an increasing number of students. As initiated this year, each fellow will have two or three students working with him.

GYORGY KEPES

## Center for International Studies

This year marked a major change in Center direction both in terms of program emphasis and in organization. A pioneering effort at its establishment in 1951, the Center for International Studies during the next 20 years provided the setting for research into problems of international relations in five areas: political and economic development; international communication; military and foreign policy; studies of communism, revisionism, and revolution; and social science modeling and methodology. With the appointment of Professor Eugene B. Skolnikoff, Head of the Department of Political Science since the fall of 1970, as Director of the Center to replace Professor Everett E. Hagen who became Professor Emeritus at the end of the academic year, the Center has moved to develop opportunities to explore the dimensions and implications of technological change and to deal more centrally with the international issues thrown up by and surrounding technology and science.

Administratively the Center has become an interdisciplinary center to facilitate closer cooperation and interaction between the social sciences and physical sciences and to provide a more accessible capability for scientists and engineers with international interests. Accordingly, instead of being housed within the School of Humanities and Social Sciences with most of those doing research under Center auspices holding faculty appointments in one of the academic departments of that School, the Center has been changed in status so that it is now an inter-School center reporting directly to the Provost. The Center in effect will be the Institute's primary, though not exclusive, mechanism for initiating and supporting international studies, especially those with a multidisciplinary character, and it should become as congenial a home for engineers and physical scientists as it is for social scientists.

New projects and ideas have been under active development with the participation of faculty

from many M.I.T. departments and from neighboring institutions. These include international impact and control of technology; comparative studies of advanced technological countries in areas such as technology policy, income distribution, and welfare policy; arms control; population and migration; and nutrition planning for developing countries.

International impact and control of technology. The political, economic, and social effect of new technology and of the increasing use of technology by a burgeoning global population is not a single subject but a category of issues clearly a natural focus of concern for M.I.T. and the Center. Within the Center, Professor Skolnikoff has been working on the implications of science and technology for the international political system; Professor Nazli Choucri Field has been examining the relations between population, resources, and technology; and Professor Hayward R. Alker, Jr., has been studying changing demands on the United Nations. A working seminar has also been established in cooperation with the Harvard Center for International Affairs on the model of the Joint Arms Control Seminar to explore in depth the direction of technological development and application, the political and other implications of those changes, the potential for control and conflict inherent in the changes, and the alternative policy choices available in political, economic, and technological dimensions. Other productive research programs are under consideration such as the international political and legal questions surrounding the rapidly changing technological environment in the oceans and the poorly understood relations between technology and trade, including the role of technological investment in economic growth, the effect of policies attempting to limit the transfer of technology among developed countries, and the effect on trade positions of new environmental and other domestic controls.

Comparative studies of advanced technological societies. Detailed research plans are being formulated for a comparative study of science and technology policies among the United States and Western European nations to be conducted by Dr. Herbert Hollomon and Professors Harvey Sapolsky and Suzanne Berger. The intention is to establish a network of collaborative partners in each country of interest, and to that end discussions have been held with several European centers. Ultimately it is hoped to include Japan in the study as well. Plans have also been made to create a joint Harvard/M.I.T. seminar under Professor Berger to focus on the common problem of income distribution in advanced industrial societies.

Arms control. The Center has taken the initiative in bringing together a group of faculty and students from M.I.T. and Harvard University to develop a revitalized program of research, teaching, public education, and government-scholar communication in the area of arms control. An essential feature of the new program is its inclusion of individuals from many disciplines, just as the concerns of scientists, economists, and political scientists in the later 1950's, particularly in the Cambridge area, combined to create a quantum jump in imaginative policy approaches to the awesome problem of controlling nuclear military technology.

Population and migration. Population growth and its effects and the closely related area of population migration, particularly rural-urban migration, have already been receiving considerable attention at the Center. Professor Nazli Choucri Field has been studying the relationship between population pressures and international and domestic violence, and Professor Myron Weiner has been examining the social and political effects of internal migration in India. A survey of other work at M.I.T. showed a large number of individuals working on a broad range of subjects varying from technical development of fertility devices to questions of the economics of labor mobility. This range of interests has been brought together and the feasibility of a comprehensive research program in migration questions that would be of wide interest to the faculty from several departments is being explored.

Technology and development. Although one of the central interests of the Center throughout

its history has been political and economic development, the relation of technology to development has only recently been singled out for primary attention. Three specific subjects indicate the Center's initial interests in this area. 1) Transfer of technology: The Center is participating in an AID grant to M.I.T. which seeks to engage Institute faculty more directly in the transfer of technology process and to expand experience and overseas contacts to make that possible. 2) Communication and development: Social scientists in the Center have been formulating with engineering colleagues a proposal for a research, planning, and training program that would establish a nation's communication needs, elaborate alternative ways of meeting all or part of those needs, and develop the implications of alternative paths. 3) Nutrition advisory function: The Center will join the Department of Nutrition and Food Science at M.I.T. in the creation of a research, planning, training, and advisory group on national nutrition policies that will be available to assist nations and international organizations.

* * * * *

At the same time that these and other programs are being developed, the Center's work on economic and political developments, communism and other radical movements, U.S. foreign and domestic policy, communications, and computer applications to social science problems has continued.

Studies of economic and political development. A collaborative research and training program with the Oficina de Planificacion Nacional in Chile to improve overall Chilean capabilities in the formulation and execution of development plans was completed in the spring of 1972. Professor Lucian W. Pye continued his program of comparative research on Asian political cultures and their relation to national development. In the spring of 1972 Professor Weiner and John Field conducted a conference examining Indian voting behavior. Professor Robert I. Rotberg continued his comparative study of African liberation movements, their leadership and internal politics, and their ideology and international relations. Ways of more closely linking the business and political sectors of black African states in order to promote economic development and decentralize the economic development process are being assessed by Professor Willard R. Johnson. Professor Pye is also conducting research on civil service personnel policies and practices in low income countries.

Studies in international communication. Professor Ithiel de Sola Pool has continued his work on the communication process in the communist world and developing countries. In collaboration with Dr. Zev Katz he has also continued his study of Soviet sociology and its impact on the Soviet system. As part of his study of group identity and political change Professor Harold R. Isaacs continued his work on ethnic identification of white Americans. Dr. Ai-li Chin is expected to publish the results of her investigations of identity patterns among American Chinese in 1972.

Studies in military and foreign policy. An expanded system of CASCON, a computer aided system for handling information on local conflict situations, is being developed by Professor Lincoln P. Bloomfield. Amelia C. Leiss continued her work on models of arms races utilizing data from her earlier arms transfer project to develop an interactive and dynamic model of arms races. Professor William W. Kaufmann continued his analysis of the rationale and allocations of the U.S. defense budget, including consideration of the budgetary and other implications of a U.S. withdrawal from Southeast Asia.

Studies on communism revisionism, and revolution. Professor William E. Griffith published a series of monographs on the Sino-Soviet-American relationship as of 1971. He is also organizing a conference among a small group of Polish and American scholars to discuss recent developments and future trends that affect U.S.-Polish relations. Professor Donald L. M. Blackmer continued his research on left-wing politics in Europe and he is

organizing a conference on nonruling communist parties. Dr. Robin Remington published a series of case studies The Warsaw Pact: Case Studies in Communist Conflict Resolution. Professor Douglas A. Hibbs continued his study of the effect of such factors as affluence, industrialization, class structure, and electoral success on Communist party strength and political stability in France and Italy.

Studies in social science modeling and methodology. Professor Alker, in collaboration with Professor H. Douglas Price of Harvard, continued his work on modeling a variety of complex political systems. He is completing a book and related papers on mathematic (cybernetic) models of political systems. Stuart McIntosh and David Griffel with Professor Pool have continued development of MARK V ADMINS including the creation of a prototype content-oriented file system and development of ADMINS language to implement the system. Professor Pool also worked on the development of his general model of social science theory, an attempt to create an interactive conversational computer program to help social scientists in evaluating and developing social theory. Dr. Rosemarie Rogers continued her work on the design of a system of rules for identifying political themes in documents in order to set up an experimental system to identify and retrieve documents.

EUGENE B. SKOLNIKOFF

## Center for Materials Science and Engineering

The Center for Materials Science and Engineering (C. M. S. E. ) has been housed in the Vannevar Bush Building since 1965. The aims of the C. M. S. E. are to encourage, fund, and coordinate interdisciplinary research in materials, based in large part on block funding by the Advanced Research Projects Agency and further supported by individual grants. Faculty, staff, and students of the Departments of Physics, Chemistry, Metallurgy and Materials Science, and Civil, Mechanical, Electrical and Chemical Engineering participate in the C. M. S. E., although funding support is not restricted to occupants of the Center. Starting July 1, 1972, funding of a major part of the Center's programs will come from the National Science Foundation.

In addition to funding support, the Center provides a series of Central Facilities supervised by senior faculty members for the purpose of providing special materials and character - izing them in specific ways, to provide analytical services, testing methods, shop facilities, etc., in support of research throughout the Institute. The Center has more than 80 faculty and research staff members associated through the funding program, and on average, 40 advanced degrees are awarded to students per year through C. M. S. E. funded programs.

Some highlights of research, highly abbreviated, are given below as examples of the types of studies which are under way. The Annual Report on Research in Materials issued by the C. M. S. E. gives a more complete view of research in materials.

Electron Microscopy Applied to Problems of Mechanical Behavior
Professor John Vander Sande, Metallurgy and Materials Science
In studies of metallic deformation, transmission microscopy has been broadly useful in studying defects. It is now possible to obtain a line resolution of 2 Å on commercially available instruments. This optical resolution does not mean that two objects giving rise to diffraction contrast can be resolved if their spacing is greater than 2 Å, for there exists one other important parameter, namely practical resolution; this resolution is determined by the overlap of normal defect images, and in usual cases this resolution is a few hundred Å Angstroms. A new technique is being applied to increase the practical resolution limit; it is called weak-beam microscopy and simply replaces wide defect images with narrow ($\sim$ 15 Å), intense ( $\sim$ 100 times background) image peaks close to, and at a determinable distance from the real-space defect. The technique is being applied, with great promise,

to both cyclic and unidirectional deformation, and has stimulated close coordination among investigators in the organized "Deformation and Fracture" thrust area.

Crystallization Behavior in Polymers
Professor Donald Uhlmann, Metallurgy and Materials Science
The latest work in this group has led to a model for the crystallization of polymers from the melt in which tight folding of the polymer chains is not assumed. This model distinguishes between the end-surface energy of the crystal lamellar surface thickness is limited by diffusion of the crystallizing chain in the liquid. The approach suggested by this model has wide-ranging implications for the resulting microstructures and properties of semicrystalline polymers and will now be extended to treat a variety of crystal growth phenomena in polymers, including fractionation, branching, and twisting.

Fatigue Failure in Glass Fiber Reinforced Plastics
Professor Frederick McGarry, Civil Engineering
Fatigue crack growth in composites requires the application of fracture mechanics concepts to, and an understanding of, the mechanisms of fracture resistance in such materials. Such studies with glass fiber reinforced plastics show that cracks in the $0^{o}/90^{o}$ crossplied and woven fabric laminates are blunted by splitting in the loading direction, perpendicular to the crack axis; the fracture work is equivalent to the work of loading the region of fibers adjacent to the split to failure, whence the crack propagates another short distance until it is terminated by a new split. The work of fracture is proportional to crack tip split length over a wide range, so material toughness is increased by low interlaminar or fiber-matrix bond strength, and is very strongly affected by ply stacking sequence. This toughening mechanism is also active in angle-ply laminates which fail in the opening mode of crack propagation. The studies will be applied to graphite fiber reinforced epoxy systems.

Recrystallization Induced by High Strain Rate Deformation at Hot Working Temperatures
Professors Regis Pelloux and Nicholas J. Grant, Metallurgy and Materials Science
A) Utilizing a cast, commercial ingot of type 304 stainless steel, the time to achieve 80 percent recrystallization in terms of the strain, strain rate, and temperature has been worked out for the entire hot working range of conditions. Times as short as 10 seconds have been established for large strain and high strain rates. Refinement of grain size from 10,000 microns (cast) to 50 microns can be achieved with very large efficiency through control of variables, with commensurate large increases in hot plasticity and cold ductility. These parameters will be checked in commercial hot rolling of cast ingots.

B) Utilizing hot worked bar stock of Nimonic 115, conditions for optimum hot plasticity of the alloy were worked out in terms of strain rate and temperature. Extreme difficulties had been experienced in forging this alloy into turbine blades; the delineation of areas of poor hot plasticity in terms of strain rate and temperature for the given structure has resulted in highly improved yield of acceptable blades.

Fatigue Crack Propagation in Shear
Professor Ali S. Argon, Mechanical Engineering
The possibility of a phenomenological plasticity correlation between fatigue crack growth in Mode I, and Modes II and III by means of a yield criterion was investigated. It was established that no such correlation is possible since fatigue cracks with smooth surfaces only grow across the largest local opening mode of displacement which is at $70^{o}$ with respect to the plane of the shear crack in Mode II and at $45^{o}$ in Mode III. Apparent in-plane crack extension in Modes II and III is only possible when crack surfaces are rough, allowing conversion of crack face shear displacements into opening mode displacements by a ratchet effect. Measured crack growth rates correlate well with this model.

Flow Characteristics at High Strain Rates in Metals Near Room Temperature

Professor Nam P. Suh, Mechanical Engineering

The transition from elastic to plastic deformation of metals and their flow characteristics at high strain rates as functions of metallurgical variables are under study, with the intent to apply these findings to such applications as forming and wear of metals under dynamic loading conditions. In this regard the constitutive relationships of annealed low carbon steel and aluminum have been investigated experimentally and theoretically as functions of grain size and duration of loading. The results obtained with annealed low carbon steel showed that the effect of grain size is important in certain loading regimes, that the upper and lower yield points can exist even under constant stress loading, and that it is unrealistic to treat the pre-yield and post-yield phenomena as being identical processes for metals which exhibit the yield point phenomenon. A dislocation model for the delayed yielding phenomenon was also advanced, which compares favorably with the experimental data available in the literature.

Chemical Synthesis Using High Temperature Lithium Vapor Species

Professor Richard Lagow, Chemistry

This excellent work, highlighted last year also, has continued to show excellent results. The striking new compounds tetralithiomethane ($CLi_4$), hexalithioethane ($C_2Li_6$), hexalithiobenzene ($C_6Li_6$), and tetralithioethylene ($C_2Li_4$), have been prepared and characterized. Now being studied are the reactions of $CCl_4$ with excess lithium atoms at 800° C in an inverted Dewar reactor, giving a yield of 94 percent, based on $CCl_4$, of the polylithiated products tetralithiomethane and tetralithioethylene. The yield of tetralithiomethane was approximately 20 percent, with a 74 percent yield of tetralithioethylene. Similar high yields are being achieved with a variety of other reactions in this series. Numerous exciting applications are foreseen.

Modulation Spectroscopy - Studies of Band Structure

Professor Peter Wolff, Physics

The modulation spectroscopy experiments are continuing; the polarization modulation equipment, constructed recently, is now producing data on a variety of semiconductors (InSb, GaSb, InAs, etc.). While much more work remains to be done in the interpretation of the data, it is already clear that this experimental process is a very powerful one, capable of providing important information about the band structure of many crystals.

Very Narrow Band Gap Materials and Band Inversion Phenomena

Professor George Pratt, Electrical Engineering

Of particular interest are very narrow band gap semiconductors such as $Pb_xSn_{1-x}Se$ alloys whose gap can be made to vanish, followed by band inversion, i.e., a reappearance of the energy gap with valence and conduction bands interchanged. Being examined are the far infrared device prospects of these systems, with particular interest in optically pumped material whose energy gap falls in the Restrahl energy gap. In this case an excited electron cannot recombine by either direct photon or phonon or photon emission. The potential to be experimentally confirmed, offers at least the possibility of high temperature materials, i.e., 180° K with extraordinary conductivities (an anomaly was predicted, and found, in the elastic constant $C_{44}$ of $Pb_{0.5}Sn_{0.5}Te$ at the band inversion point of 180° K).

Magnetic Field Enhancement of Thermopower in Semimetals

Professor Mildred Dresselhaus, Electrical Engineering

A very large increase (several orders of magnitude) in the Seebeck coefficient in graphite has been observed at 77° K when a large magnetic field is applied. This opens the way for study of other semimetals where a similar effect, produced by the phonon drag phenomenon, will be looked for.

Order-Disorder Phenomena
Professor Carl Garland, Chemistry
Following an observation of unusual behavior of $NH_4Cl$ near $T_\lambda$ and in the "disordered" phase above the transition, calorimetric and ultrasonic studies have followed. An even more fundamental probe of this unusual behavior is a measurement of the piezoelectric constant of $NH_4Cl$, $d_{14}$. Since $d_{14}$ is directly proportional to the extent of ordering, measuring it provides a direct indication of the order parameter, which is the underlying variable of all order-disorder anomalies.

In $NH_4Cl$, $d_{14}$ is very small to begin with, and then approaches zero at the transition. This requires an extremely sensitive technique in order to be able to extract useful data. To carry out these measurements, laser interferometry is employed to detect the minute vibrations of a single crystal of $NH_4Cl$ which is piezoelectrically excited. It is possible to detect vibrations as small as $10^{-11}$ cm and to do so without applying disturbances to the sample which may interfere with the ordering process being studied. The work is pursued jointly with Professor T. Greytak of the Department of Physics.

Correlation Range, Surface Tension, and Thermal Diffusivity of Xenon Near its Critical Point
Professor George Benedek, Physics
The validity of current theories for the transport properties of fluids near the critical point has been in doubt because of lack of experimental measurements of the fundamental properties of these fluids. We have made an extensive series of measurements of the compressibility range and surface tension of Xenon near its critical point. This data permit an accurate evaluation of the existing theories for the transport properties of critical fluids, and it is now demonstrated that in Xenon the current theoretical analyses describe with good accuracy the divergence of the thermal conductivity.

Thermal and Electrochemical Switching Models
Professor David Adler, Electrical Engineering
Solutions to the complete steady-state heat equations have been obtained under the assumption of no significant heating of the electrodes. It was found that pure thermal effects produce neither negative differential resistance regions nor high-current filaments. However, when some electronic effects, such as space charge, narrow Schottky barriers, or field-enhanced conductivity, are explicitly introduced, negative resistance and filamentary conduction result. The solutions then obtained are in general agreement with the available data.

NICHOLAS J. GRANT

## Center for Space Research

Studies and experiments have been continued over the past year in the Center for Space Research in the general field of space science and engineering involving projects under the supervision of approximately twenty faculty from the Departments of Physics, Earth and Planetary Sciences, Aeronautics and Astronautics, and Electrical Engineering. This research has been supported by the efforts of approximately 60 full-time research staff, and 60 hourly and biweekly personnel. About 30 students have been directly involved under fellowship appointments and research assistantships, and 35 more on part-time employment.

In previous reports from the Center, the specific objectives and programs of the several ongoing and proposed space flight experiments were described in some depth. Significant developments in the several programs will be touched upon in this report. The other activities of the Center for Space Research will also be updated. The portion of the Department of Physics report dealing with cosmic ray and interplanetary plasma research should be consulted for additional discussion of objectives and results from this research.

The Interplanetary Monitoring Platform (IMP) program under the supervision of Professor Herbert S. Bridge is continuing generally as planned. The flight unit for IMP-H has been completed and extensive tests and calibrations have been made prior to delivery for the launch currently scheduled for late summer of 1972. The IMP-J unit is being assembled and tested preparatory to launch in 1973.

The data gathering from the Orbiting Solar Observatory (OSO-7) program under the supervision of Professor George W. Clark is proceeding as planned after launch took place in September, 1971. Among the many important new contributions to our knowledge about x-ray sources which this experiment is yielding is, in particular, a 20-day observation which revealed, within a pattern of variation in periods of relatively steady emission lasting several days, an interruption by violent flaring having x-ray intensity variations of factors of two and three on a time scale of minutes. Correlation of these data with other observations made by balloon- and rocket-borne payloads and by optical observations are leading to hopes that the major astronomical puzzle surrounding Sco X-1 can be eventually solved.

The Small Astronomy Satellite (SAS) flight hardware design and fabrication are proceeding on schedule. The prospective launch date of this payload is for April, 1974. The principal investigator for the SAS program is Professor George W. Clark with Professors Hale V. Bradt, Walter H.G. Lewin, and Herbert W. Schnopper as co-investigators.

The x-ray astronomy experiments from sounding rockets under the supervision of Professor Hale V. Bradt with the assistance of Professor Saul A. Rappaport, have continued to add important new information concerning x-ray data in the 1-10 KeV energy range. The May, 1971, launch yielded important new x-ray data including the celestial positioning of Cyg X-1, GX 349+2, and GX 340+0 to a precision of about one second of arc. Cyg X-1 was shown to exhibit rapid fluctuations in x-ray intensity in that changes by factors of two or more in time scales of fifty ms to several seconds were observed. No evidence was found for true x-ray pulsar activity in the frequency range of 0.2 Hz to 100 Hz despite the interpretations of Uhuru data to the contrary. No flaring or pulsing activity was found in the x-ray signal from GX 349+2 or GX 340+0. A new rocket payload was launched in May, 1972,to map the angular structure of Vela X and the Cyg loop supernova remnants. Data reduction from this last flight is in process.

The Mariner-Venus-Mercury mission, which will study the plasma regime at the planet Mercury and the interaction of the planet Venus with the solar wind, is in an advanced stage of hardware design and fabrication. The spacecraft is scheduled for an October, 1973, launch. This research is under the supervision of Professor Herbert S. Bridge.

The x-ray astronomy from high-altitude balloon experiments, under the supervision of Professor Walter H.G. Lewin, had one of its most successful flights on April 5, 1972, in which the telescope was carried aloft to a maximum altitude of about 150,000 feet on a 46.1 million cubic foot Winzen balloon. The successful flight of this balloon set a world's record so far as the size of the balloon was concerned. A second flight was achieved a few days later. The data from these flights show evidence of making further major contributions to our knowledge of extraterrestrial x-ray sources.

Professor Herbert W. Schnopper has undertaken the design and construction of a two-crystal spectrometer for use in the x-ray spectroscopy experiments to be carried out aboard the Astronomical Netherlands Satellite (ANS) experiment.

Definitive contracts were negotiated and signed effective May 1, 1972, for the High Energy Astronomy Observatory (HEAO) flight hardware design and fabrication (Lewin) and the science support (Bradt) phases of the Mission A-HEAO spacecraft. The experiment under Professor Bradt's supervision is being designed to determine celestial positions of sources

to about five arc-second accuracy as well as angular size to about five to ten arc seconds in eight energy bands from 0.18 to 20 KeV. Studies will also be made of the angular structure of x-ray emission to a precision of ten arc seconds at eight energy levels. Professor Lewin's experiment will determine position and intensity of extra-galactic x-ray sources over an energy range from 10 to 150 KeV, and will detect galactic x-ray sources within $10^{o}$ of the galactic equator. Launch of Mission A of the HEAO series is scheduled for 1975.

Theoretical studies closely allied with the flight programs described heretofore are being carried out in the Space Center by Professors Stanislaw Olbert and Vytenis M. Vasyliunas and Dr. Alan J. Lazarus. As the flight data yield new insights into the astrophysical phenomena of the universe, so it is possible to extend, revise, and sometimes abandon the various theoretical interpretations which have been devised to explain these phenomena.

Closely related to this research have been the theoretical studies of the Astrophysical Group of the Department of Physics. These efforts, jointly sponsored by NASA and NSF, have continued to reveal new insights into the behavior of quasars, pulsars, supernova light emissions, and related phenomena (Professor Philip Morrison); stellar evolution and stellar pulsation (Professor Icko Iben, Jr.); and hydrodynamic studies of planetary nebula ejection (Professor William K. Rose).

A renewal and expansion in the interests of the staff of the Space Center have taken place during the year in the establishment of active research in infrared observations and studies. A new program concerned with the determination of IR light curves for a number of solar system objects (asteroids and comets) and stellar observations of cool stars known to be associated with OH emission, will be undertaken by Dr. Susan G. Kleinmann in collaboration with Professors Thomas B. McCord and Alan H. Barrett. These observations will involve adaptation of the M.I.T. Wallace Observatory's 24-inch telescope. Dr. Kleinmann will become an Assistant Professor in the Department of Physics in September, 1972.

The lunar Surface Electrical Properties experiment (SEP), under the supervision of Professor G. Simmons of the Department of Earth and Planetary Sciences and Professor John V. Harrington of the Space Center, has made significant progress during the year in developing, supervising the building, and testing the transmitter and receiver equipment necessary to carry out the electronic probing of the lunar surface as a vital part of the Apollo 17 mission. Field tests at the Athabasca Glacier in Alberta, Canada, were carried out in the fall of 1971; these revealed much new information pertinent to the design of the experiment hardware. Additional tests on the ice fields of the Juneau Glacier in Alaska in June, 1972, using the breadboard and prototype equipment, have yielded significant results on operational technique and data interpretations which will be important to the understanding of the data to be taken on the lunar surface in December, 1972. Key responsibilities for the design and fabrication of the necessary flight hardware have been borne by the Center's Dr. James W. Meyer and Richard H. Baker.

The cooperative study on Domestic Information Networks User Requirements have been completed for NASA by Professors John V. Harrington, Jack P. Ruina, George W. Rathjens, Ithiel D. Pool, and others during the year. Final reports are in preparation and will be submitted to NASA during the summer of 1972.

An important milestone was passed with the receipt by the Center in March, 1972, of the new NASA Space Technology Grant NGL 22-009-638 which, when combined with the residual funding from the NASA Sustaining University Grant NGL 22-009-019, will permit the evolution of a space technology research and development activity of about $200,000 per year. The availability of relatively uncommitted funding of this type is considered to be of utmost importance to the Space Center's future, because it is only through this medium of

unrestricted funds that new ideas and concepts for new programs are nurtured and developed to the stage where they can become viable prospects for direct support by interested mission sponsors. Active projects are developing in this area, and it is expected that they will lead to some of the new programs to which the Center will look for its future.

Administrative support has been provided by the Space Center for several projects of related interest on the campus. Chief among these has been the Manned Vehicle Laboratory under the supervision of Professor Laurence R. Young, which has carried out a variety of experimental and study programs in the area of dynamic control and the role of the human vestibular organs in manned atmospheric and space flight.

The overall activities in the Center for Space Research have continued to show a significant increase during the past year, requiring the addition of new staff and support personnel and facilities. The total research volume for the Center has grown to about $5 million exclusive of major subcontracts for the year 1971-72. With the emphasis developing on the SAS and HEAO programs, a further growth to about $6 million, exclusive of major subcontracts, is expected in the year 1972-73. While new research space in the form of laboratories and offices has been required to house the additional personnel, the planning has been carefully laid so as to obviate the necessity for large, fixed research facilities having short useful lives and thus severe future disposition problems for the Institute. Maximum advantage has been taken of industrial supply and subcontract facilities for similar reasons. This aspect of the Center's activities has required emphasis to be placed on enhanced management practices and procurement procedures for which the Center owes much to the cooperation and assistance of the M.I.T. Division of Sponsored Research.

JOHN V. HARRINGTON

## Clinical Research and Arteriosclerosis Centers

The Clinical Research Center, which opened in 1964, is a small, fully equipped and staffed, research hospital on the M.I.T. campus. The major purposes of the Center are to enable M.I.T. faculty members to apply their expertise to the problems of human disease in a clinical setting, and to allow students at all levels to gain experience in working with patients. Many research projects are in progress including those in nutrition, psychology, cardiology, endocrinology, and mechanical, chemical, and electrical engineering. The studies in most cases are collaborative, involving both basic scientists and clinicians.

Medical services for subjects under study at the Center, including nursing care, laboratory tests, and therapeutic measures, are provided under a grant from the General Clinical Research Centers Branch of the National Institutes of Health's Division of Research Resources. Patients and normal subjects may therefore be seen as outpatients or hospitalized as inpatients at no cost to them. The facilities of the Center are open to all departments in the Institute, and its staff consists of members from many of those departments. Although most patients hospitalized in the Clinical Research Center come from the Boston metropolitan area, a significant number are referred from other parts of the United States, and some are referred from abroad.

The Clinical Research Center has been a natural focal point for M.I.T.'s new programs in medicine including those wholly based at M.I.T. as well as the joint programs with Harvard Medical School. Under the direction of Dr. Robert S. Lees, the Center has begun research projects in patient data management, clinical laboratory automation, computer diagnosis, evaluation of risk factors for coronary heart disease, and several approaches to noninvasive diagnosis of cardiovascular, particularly arteriosclerotic, disease. These projects involve extensive collaboration with the Charles Stark Draper Laboratory of the Institute, and provide a realistic introduction to medical science for a large number of

undergraduate and graduate students in both engineering and natural sciences.

A natural outgrowth of the cardiovascular research projects is the M.I.T. Arteriosclerosis Center, established at the end of academic 1971 as a Specialized Center of Research of the National Heart and Lung Institute. The Arteriosclerosis Center provides both new physical facilities for clinical cardiovascular research contiguous to the Clinical Research Center and funds for the continuation and extension of many of the research projects mentioned above. The creation of the Arteriosclerosis Center and the realization of its goals will not only expand further M.I.T.'s involvement in and contribution to the diagnosis and care of sick patients, but will also involve close long-term collaboration with Harvard Medical School and the Massachusetts General Hospital (MGH).

The Arteriosclerosis Center's staff includes members of the Departments of Medicine and Pathology, and of the Clinical Laboratories of MGH. Many of the research projects of that Center will be conducted in part within the hospital. The Arteriosclerosis Center's clinical director, Dr. Gordon S. Myers, visiting Associate Professor of Medicine at M.I.T., is a physician at MGH and Associate Clinical Professor of Medicine at Harvard Medical School. The information storage and processing needs of the new Center, as well as instrumentation development, are the responsibility of a group from the Draper Laboratory, under the direction of F. Keith Glick and Richard A. Metzinger, Assistant Directors of the Laboratory.

The work of the Arteriosclerosis Center has just begun; its physical facility is not yet built. Nevertheless, it gives every prospect of participating fully in M.I.T.'s programs in medicine in the future.

ROBERT S. LEES

## Education Research Center

During the past year the programs and projects carried out by the Education Research Center (E.R.C.) have undergone some consolidation within the Institute. The range of E.R.C.'s immediate and long-term interests continues to include new concepts in curriculum methods and materials in such diverse areas as physics, mathematics, educational use of films, and self-initiated science projects. In addition, E.R.C. staff members this year decided to devote a larger proportion of their time and energy to planning, devising, and structuring curricula which will ultimately help young men and women from minority groups enter medical and para-medical careers. E.R.C. has also begun to formulate a research plan to study learning problems in reading and in mathematics with an eye to setting up a laboratory for the treatment of such problems.

As in the past, the Education Research Center continued to work closely with many departments of the Institute, as well as other educational institutions, in testing and proliferating innovative science courses and their complementary materials. The following projects, funded chiefly by foundation grants, were actively pursued during the year 1971-72.

### Unified Science Study Program

The past year was the third year of operation of the Unified Science Study Program (U.S.S.P.). U.S.S.P. was conceived as the first step towards a national program of educational reform. Initially established for college freshman, it has been extended in one form or another to include grades 11-14, and it is now viewed as a vehicle for entry and re-entry into the "career ladders" of most sciences and technologies.

The work in U.S.S.P. is based on open-ended projects of individual choice and design. Many different modes and styles of study are utilized, as students are given a major degree of responsibility in determining the content, style, and pace of their own undergraduate education.

During the past year, students in U.S.S.P. took, among other programs, the newly developed "What People Eat," a one-year, half-time laboratory and seminar subject covering chemistry, biology, nutrition, and some aspects of pre-calculus mathematics and physics. As its point of departure, this program focuses on the qualitative and quantitative analysis of the students' own food intake and its physiological consequences.

Students in U.S.S.P. also constructed a laboratory for demonstration and experimentation in visual perception. Currently in the planning stage is a one-term subject in perception, which will use this laboratory as its base. The substance of the subject will be the students' own psychological processes studied in the self-paced style. Subject materials will consist of a short expository text, a laboratory manual, quizzes, and additional, inexpensive equipment. The subject in perception will assume no prior knowledge of psychology.

Approximately 100 students were engaged in U.S.S.P. studies this past year. In addition to M.I.T. students, men and women from North Shore Community College, the University of Massachusetts at Boston, Keene (New Hampshire) State College, and the Boston Model City Higher Education Program participated in the Program.

## Education Research Center Colloquia

The Education Research Center continues, as in the past, to sponsor a weekly open colloquium on E.R.C. projects and on topics of general interest in the area of education. A few of this year's presentations included: the videotape of a speech on Attica Prison by New York Times' columnist Tom Wicker; a discussion and demonstration of the PLATO Computer-Based Instructional System; and a talk on Piaget by Robert B. Davis of Syracuse University. This weekly series of lectures, films, and discussions serves both as a public forum and a means of informing the education community about the work and interests of E.R.C.

## Computer Generated Films

Since 1966, when this NSF-funded program began more than 20 computer generated films have been produced by E.R.C., four of them this past year. These films, in the form of loops, cover such topics as quantum mechanics, physical chemistry, electrodynamics, and biochemistry. Computer-animated, they are especially suited to demonstrating phenomena that are either too small or too rapid to be observed directly. E.R.C. film loops are available commercially. Single-frame "stills" taken from these films have appeared in many of the recently published college physics texts.

## Graduate Interdisciplinary Degrees

The Education Research Center has been awarded a grant by the Carnegie Corporation to plan and develop a doctoral program in interdisciplinary studies for men and women who wish to enter college teaching as a professional career. This innovative program puts a premium on a student's ability to assimilate, synthesize, and disseminate knowledge and understanding, rather than solely on his or her gift for research. Eligibility for the program requires admission to a graduate department at M.I.T. Degree requirements are based on overall interests and career objectives. As of now, five students are enrolled in this program and are working in a variety of fields.

## Laboratory, Computer, and Calculus Based Subject in Mathematics

This is the second year of E.R.C.'s laboratory based subject in mathematics, devised as a part of the Unified Science Study Program with particular emphasis on needs outside of

M.I.T. During 1971-72, 61 students from more than five colleges took this subject. The lab-math program at E.R.C., which requires only a rudimentary competence in arithmetic, capitalizes on the intuitive nature of calculus, student interest in computers, and the use of a laboratory in which abstractions are rendered concrete. Students in this subject self-paced themselves through 15 units of work, concentrating heavily on their own work in the laboratory and on computers.

## M.I.T. — D.I.T.

Since the spring of 1971, the Detroit Institute of Technology (D.I.T.), an urban school of science and technology, has been involved in a joint program with M.I.T. to improve the quality of its academic programs. Known at D.I.T. as the New Study Program, the Program was broadened in 1972 to include more subjects in both science and the humanities, as well as more students. During the month of June, 1972, a group of D.I.T. faculty members and a small number of their students came to E.R.C. where they worked together on the improvement and the extension of the New Study Program. D.I.T.'s primary goal is to educate disadvantaged men and women from Detroit's inner city, emphasizing skills that rest on a solid foundation of mathematics, physical science, social science, engineering, and communications. M.I.T. is assisting D.I.T. in reaching this goals by providing new curriculum methods, materials, and personnel support.

## The M.I.T. Introductory Physics Series

This past year marked the twelfth year of this project, funded by the National Science Foundation. This physics series has produced three texts and a great many filmed demonstrations, laboratory learning aids, and background documentation, all of which are extensively used in M.I.T.'s physics subjects. Two more texts are in preparation.

## Secondary School Teachers Program

For six weeks during the summer, 24 teachers from high schools around the country worked at E.R.C. on the development of innovations in teaching materials and/or teaching approaches which they originated themselves. This program, now in its second year, is funded by the National Science Foundation. The teachers who come to E.R.C. are selected on the basis of team proposals submitted during the academic year. E.R.C.'s staff members provide guidance and assistance in developing materials which the teachers take back to and use in their own classrooms in the coming school year.

## Self-Paced Study and Instruction

The self-paced mode of learning, whereby a student learns within a timetable of his own making, has been successfully tested at M.I.T. during the past few years. A student in a self-paced study program works with study materials built as sequential units of work. There is no failure of units -- rather, mastery of each unit is the only criterion of progress. M.I.T. is actively involved in the development of self-paced math, physics, chemistry, and other subjects, which are all available to M.I.T. students, some under U.S.S.P.

To date, self-paced instruction, known also as the Keller Plan, provides curriculum materials used by M.I.T. students in more than a dozen subjects in eight departments. In addition, materials and information have been distributed to several hundred schools through E.R.C. mailings, workshops, conferences, and visits by staff members. The program has been funded by the National Science Foundation, the Schlumberger Foundation, and the Esso Foundation.

## Undergraduate Research Opportunities Program

The Undergraduate Research Opportunities Program (U.R.O.P.) is a well-established and widely accepted mode of involving students in a professional level of laboratory work at M.I.T. Since 1969 E.R.C. has made this opportunity available to all M.I.T. students who want to be involved in the ongoing research of a faculty member. E.R.C. publishes a Directory of Undergraduate Research Opportunities every term. M.I.T. students who take advantage of these research opportunities are awarded either academic credit or an appropriate wage.

JERROLD R. ZACHARIAS

## Electric Power Systems Engineering Laboratory

Professor Gerald L. Wilson was appointed the Director of the Electric Power Systems Engineering Laboratory after Professor Woodson, the laboratories first director left M.I.T.

Associated in the laboratory are Professors Charles Kingsley, Jr., Fred C. Schweppe, Herman M. Schneider, and James L. Kirtley, Jr. of the Department of Electrical Engineering and Professors Philip Thullen and Joseph L. Smith, Jr. of the Department of Mechanical Engineering. The laboratory now consists of 40 graduate and undergraduate students and a staff engineer.

The electric utility industry continues to face increased demand for electric power with increasing challenges placed by environmental and technological effects. The laboratory's goal is to train engineers to meet these challenges by creating for students the opportunity to work on problems arising from these challenges.

Research in the laboratory ranges from studies of new methods of power generation, including the development of a superconducting alternator in a joint project with the Cryogenic Laboratory, to the effects of increasingly high voltages on transformers, circuit breakers, transmission lines and other components. A large, two phase, modeling project is in progress which enables students to model the effects of switching operations on transmission systems as well as study problems associated with system protection and control utilizing detailed physical scale models of power system components.

Several projects in the area of plasma and arc physics as applied to power systems are in progress including studies in insulator contamination, vacuum breaker arcs and audible noise on UHV transmission lines.

A large portion of the laboratory's efforts is in the area of power system measurement and control using digital computers. Studies include short-term load forecasting, nuclear reactor control, methods for obtaining generator equivalents and associated application of state estimation theory to power system problems.

Work is also in progress in association with the Continuum Electromechanics Laboratory under the leadership of Professor James R. Melcher in the area of developing agglomerators for electrostatic precipitators.

At present, the laboratory involves the cooperative efforts of electrical, mechanical, and nuclear engineers. Plans for work on Contained Bulk Power Transmission may well increase the scope of participation to include faculty and students from the Departments of Civil Engineering and Economics.

GERALD L. WILSON

## Francis Bitter National Magnet Laboratory

The first year of the Laboratory's sponsorship by the National Science Foundation was marked by steady progress in the basic scientific research program, as well as an extension of the applied programs aimed at practical applications of magnetic fields.

Measurements at very high magnetic fields on new forms of the superconducting compounds $V_3Ga$ and $Nb_3Ga$ show these materials to be very promising for the construction of high field superconducting magnets. The superconducting tunneling technique developed here last year has been used to study the polarization of tunneling currents into ferromagnetic metals and spin state mixing in superconductors in high magnetic fields. Further development of the theory and new experiments on the tunable high intensity spin-flip Raman laser were carried out. Important new results on laser produced plasmas in high magnetic fields have been obtained in a program supported by the Air Force Office of Scientific Research. A novel proposal for an X-ray laser also originated from work under this contract.

Unforeseen engineering problems and insufficient funding have delayed initial operation of the Alcator thermonuclear machine. A reorganization of the effort and increased participation by the Research Laboratory of Electronics and the Department of Electrical Engineering have given new impetus to this program. An initial study of a magnetically suspended and propelled high-speed ground transportation system, called Magneplane, has been supported by the M. I. T. Sloan Fund. Additional studies and construction of a working model will be supported by NSF under its Research Applied to National Needs (RANN) program.

In another RANN supported program, studies of various schemes to separate pollutants from fuels and weakly magnetic minerals from ores using high magnetic field separation techniques have produced promising results.

Requests for use of the magnet facilities from our own staff and from visitors have considerably exceeded the time available. To ease this situation, NSF core support of the Laboratory has been increased for the coming year to allow a resumption of two shift operation. RANN support has been obtained for programs on magnetocardiography, liquid nitrogen-cooled power transmission lines, magnetic separation of pollutants from water and an improved magnetically guided catheter system. However, additional support is needed for the basic research program. It appears that this important segment of the Laboratory's program will continue to shrink under the impact of static funding and inflation. New efforts are required to reverse this trend.

BENJAMIN LAX

## Harvard—M.I.T. Program in Health Sciences and Technology

The Harvard-M. I. T. Program in Health Sciences and Technology has been established by Harvard University and M. I. T. as a major collaborative effort designed to focus science and technology on human health needs. The complementary strengths of both institutions are directed to developing new kinds of physicians and other health scientists, to applying modern science and technology to health problems and to better integration of the natural and social sciences, engineering, and management with education and health care.

An Executive Committee for the Program has been established and consists of the following officers and faculty members of the two universities: Jerome B. Wiesner, President, Massachusetts Institute of Technology, Co-Chairman; Robert H. Ebert, Dean, Harvard Medical School, Co-Chairman; Robert A. Alberty, Dean of Science, Massachusetts Institute of Technology; Robert S. Blacklow, Assistant to the Dean, Harvard Medical School;

Derek C. Bok, President, Harvard University; Harvey Brooks, Dean of Engineering and Applied Physics, Harvard University; John T. Dunlop, Dean, Faculty of Arts and Sciences, Harvard University; Paul E. Gray, Chancellor, Massachusetts Institute of Technology; Howard H. Hiatt, Dean, School of Public Health, Harvard University; Walter L. Koltun, Assistant Director for Resources, Harvard-M.I.T. Program in Health Sciences and Technology; Irving M. London, Director, Harvard-M.I.T. Program in Health Sciences and Technology; Henry C. Meadow, Associate Dean, Harvard Medical School; Walter A. Rosenblith, Provost, Massachusetts Institute of Technology; and Irwin W. Sizer, Dean, Graduate School, Massachusetts Institute of Technology.

To help in guiding and supporting the Program, a National Sponsoring Committee has been formed. Its members are: Charles F. Adams, Co-Chairman; George W. Thorn, Co-Chairman; Peter Bing; Detlev W. Bronk; Paul C. Cabot; Edward W. Carter; James M. Faulkner; Elisha Gray, II; Crawford H. Greenewalt; Richard D. Hill; John L. Loeb; Eugene McDermott; William P. Murphy; Emanuel R. Piore; H.I. Romnes; George Russell; James A. Shannon; Frank Stanton; Charles Allen Thomas; and Uncas A. Whitaker.

The Program's activities cover three broad areas -- education, research, and development -- and are related to ongoing programs in health care planning and management at M.I.T. and Harvard.

## Educational Programs

*Biomedical Sciences*

The following new subjects were offered for the first time in 1971-72: Functional Anatomy of Man; Human Pathology; Cardiovascular Pathophysiology; Endocrinology; Gastroenterology; Hematology; Bone, Connective Tissue and Skin; Reproductive Physiology and Human Sexuality; Epidemiology and Biostatistics; Biochemical Basis of Clinical Disorders; Social Issues in Medicine; Ethical and Social Issues in Bio-medicine; Human Biology and Ecology; and Physiological Anthropology.

New subjects under development this year to be presented in 1972-73 include: The Human Nervous System; Biochemical and Physiologic Pharmacology; Respiratory Pathophysiology; Renal Pathophysiology; Mechanisms of Microbial Pathogenesis; and Introductory Clinical Experience and Examination of the Patient.

In addition, the Program sponsored the Health Services Project Planning Laboratory and a seminar entitled Psycho-Social Impact of Technology.

A first class of 25 graduates of M.I.T., Harvard College, and Radcliffe College was admitted into the Program in September, 1971. A special admissions committee composed of faculty members drawn from M.I.T., Harvard Medical School, Harvard College, and Radcliffe College was formed to evaluate applicants to the Program. A second class of students has been selected for the Program and will enter in September, 1972. This second group of 25 students includes pre-baccalaureate, graduate, and postgraduate students at Harvard University and M.I.T., as well as some graduates of other universities. The curriculum is oriented toward students with a strong interest and background in the natural sciences or engineering or in other fields of quantitative science.

The subjects developed for this curriculum represent the joint efforts of life scientists and physicians, physical scientists and engineers, and social and behavioral scientists selected from the faculties of both universities.

The subjects are offered on a semester pattern which conforms to the schedules of the two

universities. This pattern enhances the ability of the students in the Program to pursue studies of interest to them in other fields in the universities and also makes these subjects available to qualified students who are not candidates for the M.D. degree.

*Biomedical Engineering*

A new interdepartmental graduate program in biomedical engineering has been established during the past year at M.I.T. This new program is designed primarily for graduate students who seek to pursue biological or medical study, as well as engineering study, in depth. Students admitted to the program are expected to have had introductory subjects in general biology and chemistry or to rectify these deficiencies during the first year of graduate study. The degree requirements are specified by the Biomedical Engineering Committee, whose Chairman is Professor Laurence Young. The other members are Dr. W.G. Austen, Professor G. Benedek, Professor W. Bossert, Professor G. Brownell, Dr. S. Dawson, Dr. P.A. Drinker, Professor M. Eden, Professor D. Epstein, Dr. M.W. First, Dr. M.J. Folkman, Dr. E. Henneman, Professor R. Kronauer, Dr. R. Lees, Professor R.W. Mann, Professor C.K. Colton, Professor W. M. Rohsenow, Professor R. Rose, Professor A. Shapiro, Professor W. Siebert.

In general most programs will consist of two equal parts: 1) graduate subjects providing both breadth and depth in some areas of engineering knowledge and 2) subjects in the life sciences and bioengineering including both biochemistry and human physiology in depth appropriate to the thesis area. Students will be expected to complete early in their programs a master's thesis or project of comparable depth if the student already has a S.M. degree. Such a thesis or project is an integral part of the training program, providing a mechanism for bringing students and faculty together in the laboratory early in the program, as well as preparation for the major research effort of the Ph.D. thesis. Qualifying and general examinations for the doctorate in biomedical engineering will be arranged individually by the biomedical engineering committee for each student.

The following subjects in biomedical engineering have been offered and presented under the auspices of the Harvard-M.I.T. Program: Biomedical Fluid Mechanics; Biomedical Heat and Mass Transfer; Topics in Biomedical Engineering; Biomechanics; Biological Effects and Medical Applications of Ultrasound; Biological Effects and Medical Applications of Non-ionizing Radiations; Biomedical Materials; Science and Engineering of Biological Membranes and Structural Tissue; Biophysical Chemistry; Introductory Physics I, II, III and IV; Physical Aspects of Nuclear Medicine; Introduction to Systems Analysis with Physical Applications; and Fluid Flow in the Human Body.

A new subject, Introduction to Medical Engineering Practice, to be presented largely in the setting of the Harvard teaching hospitals will be offered in the academic year 1972-73.

A biomedical program is being developed at the West Roxbury Veterans Administration Hospital with particular emphasis on the study and treatment of spinal cord injury. This program is being developed by representatives of the Veterans Administration, Harvard Medical School, and by Professor Robert W. Mann of M.I.T.

Another important development is the award of a planning grant for the establishment of the Harvard-M.I.T. Rehabilitation Engineering Center. This planning grant from the Social and Rehabilitation Service of the Department of Health, Education, and Welfare will initiate the development of a Rehabilitation Engineering Center at M.I.T. and at the Children's Hospital Medical Center. Professor Robert W. Mann and Dr. Melvin J. Glimcher are Co-Chairmen of the Planning Committee for this Center.

Responsibility for the development of these educational programs is vested in the following committees: Educational Development Committee. Irving M. London, Chairman. This committee is responsible for overall supervision and policy determination. Its two principal

subdivisions are the Committee on the Biomedical Sciences, Dr. David Hamilton, Chairman, and the Committee on Biomedical Engineering, Professor Laurence Young, Chairman. Subcommittees of the Biomedical Sciences concerned with specific facets of the curriculum include the Basic Medical Sciences subcommittee, Dr. David Hamilton, Chairman; the Clinical Sciences subcommittee, Dr. Eugene Braunwald and Dr. Melvin Glimcher, Co-Chairmen; the Physical Sciences subcommittee, Professor George Benedek, Chairman; and the Social Sciences subcommittee.

The relationship of these educational programs to the curricula of M.I.T. and Harvard Medical School is fostered by 1) the service of Professor Hartley Rogers, Chairman of the M.I.T. Faculty, and of Dr. David Freiman, Chairman of the Curriculum Committee of Harvard Medical School, in the Educational Development Committee; 2) Dr. David Hamilton's service on the Curriculum Committee of Harvard Medical School; and 3) the fact that all members of the M.I.T. Committee on Biomedical Engineering serve on the Harvard-M.I.T. Committee on Biomedical Engineering and that Professor Laurence Young is Chairman of both committees.

## Research and Development

The Program concentrates on important health and medical problems that are especially suited to the strengths afforded by the two universities, and it seeks to conduct research in a multidisciplinary manner and on a scale commensurate with the dimensions of the problems.

The first major research effort under the auspices of the Program is "A Multidisciplinary Research Program in Biomaterials Science." This program involves 38 faculty members in 18 research projects which have developed during the course of a series of seminars held during the past two years. These projects may be divided into four categories: 1) the characterization and development of surfaces which can remain in contact with blood without forming thrombi or altering the composition of the blood; 2) the structure of natural and synthetic membranes and their dynamic behavior, and heat transport in blood and other tissues; 3) mass transport in the vascular system; and 4) the development of new instruments and techniques for the study of biomaterials. This program has been approved and funded as of January 1, 1972, by the National Heart and Lung Institute at a level of approximately $1 million annually for five years. Professor Robert W. Mann, the principal investigator, and a Steering Committee whose members are Dr. H. Frederick Bowman, the Executive Officer, and Professors George Benedek, John F. Burke, S. Roy Caplan, Philip A. Drinker, Alvin Essig, Edwin W. Salzman, David P. Waugh, and I.V. Yannas are responsible for the overall direction of the program.

During the past year, research task groups have been formed to explore the possibilities of fruitful collaborative effort in the fields of cardiopulmonary physiology and pathology and in radiation therapy and radiobiology. Dr. Edwin W. Salzman is serving as chairman of the organizing committee for cardiopulmonary studies and Dr. Samuel Hellman for radiation therapy studies. Cardiopulmonary subjects under consideration are: circulatory assistance; pulmonary assistance; diagnostic techniques for the circulatory system; and the control of the circulation. In the field of radiation, groups are working on the use of particulate radiation in the treatment of malignant disease; possible methods of studying the state of oxygenation of tumors and its possible effect on radiation therapy; patient therapy data; collection, storage and retrieval; optimization of dose distribution to tumors; diagnostic techniques for detection of cancer cells; and isotope therapy of malignant disease.

Other groups are being organized in radiologic diagnosis and nuclear medicine.

Dr. Irving A. Berstein has been appointed as Program Officer for Research and Development to facilitate the establishment of these research programs.

The implementation of the Program in Health Sciences and Technology has stimulated the growth of interest in the planning and management of health services at M.I.T. During the past year faculty members from the Sloan School of Management, the Department of Urban Studies and Planning, and the Program in Health Sciences and Technology, Professors Edward Roberts, Lloyd Rodwin, and Irving M. London, have initiated planning for the development of a coherent and integrated program at M.I.T.

Another related development is the study by the Medical Department led by Dr. Albert O. Seeler, of the feasibility of establishing a pilot program of comprehensive health care on a prepaid insurance basis for members of the M.I.T. community and their families. An affirmative recommendation has been made, and a decision is expected in the near future.

IRVING M. LONDON

## Independent Activities Period

This past year was the second of a three-year experiment in calendar reform, which was voted by the Faculty in the spring of 1970, aimed at determining alternative ways of breaking up the academic year in order to allow students and faculty more concentrated time for independent study and research.

There is no requirement that students remain on campus during the January Independent Activities Period, but housing and dining statistics show that at least 70 percent of the students were on campus at that time. During January, an assortment of over 600 separate activities, many initiated by the students, were offered. The activities ranged from astrophysics and auto repair through geostrophic turbulence and grand cuisine to X-ray crystallography and yoga. The amazing number, scope, and variety of I.A.P. events is evidence of the range of the spontaneous interests and initiatives of individual students, faculty, and staff. Each department, center, and laboratory had a faculty coordinator to help those with the various ideas get started; the Provost's Office provided the administrative help necessary to coordinate and advertise I.A.P. events.

The Guide to I.A.P. Activities resembled in style and format an underground newspaper. Printed on newspaper stock with detailed art work and graphics, the Guide was particularly well received by students, and, perhaps more than anything else, it best reflected the informal and spontaneous spirit of I.A.P., a spirit which contributes greatly to the success of the program.

A formal report on the first I.A.P. (January, 1971) was developed by the I.A.P. Policy Committee, through a questionnaire and the sampling of attendance figures. It concludes that the first I.A.P. was generally well received by most of the M.I.T. community. All evidence suggests that the second I.A.P., measured in terms of activity and interest, was even more successful. January, 1973, will be the third experience. When it is over, the same committee will report to the Faculty with recommendations on the future of this attempt at calendar reform.

JOEL ORLEN

## Information Processing Services

The 1971-72 year was marked by a number of changes in the organization under which the Institute's information processing services activities are managed. In addition, the year saw the development of several long-range technical directions and plans that will allow a more profitable concentration of our efforts during the next three years.

## Organization

In August, 1971, the Office of Administrative Information Systems (O.A.I.S.) was established by combining the Office of Administrative Systems and the Comptroller's Data Processing Office. This Office is responsible for the provision of administrative systems design and data processing services for the Institute's financial and administrative offices, academic departments, and interdisciplinary laboratories and centers.

On October 26, 1971, the Joint Harvard-M.I.T. Batch Processing Computer Facility began operation on computer equipment located on the campuses of both institutions. Establishment of this facility was planned during the spring of 1971 for the purposes of reducing costs and increasing the opportunities for intellectual cooperation between faculty and students at the two institutions. The Joint Facility meets the current batch processing needs of the two institutions with a minimum of excess capacity, thus providing the fullest possible equipment utilization at the lowest possible cost.

On December 1, 1971, the Programming Development Office (P.D.O.) was created and initially staffed through a total transfer of the Systems Programming Group of the Information Processing Center. The P.D.O. is responsible for the detailed planning, development, and maintenance of operating systems to meet the needs of the Institute's computer service facilities.

## Facility Operation

Information Processing Center. During the year, the Information Processing Center(I.P.C.) continued to provide approximately two-thirds of the computer service utilized by the M.I.T. community.

The most significant activity for the Center during the year was the integration of the Harvard and M.I.T. user communities into a single batch processing service environment. The equipment involved became operational in October and, following an initial period of shakedown, tuning, and adjustment, has been operating smoothly. Approximately 20,000 jobs are processed for each institution each month and annual savings of approximately $500,000 have been realized at each university.

A second major effort for the I.P.C. involved the establishment of improved internal cost control, budgeting, and user billing systems. These reports provide not only resource control and utilization information, but also specific input to the process for planning new services and for the modification of existing services.

A third major effort during the year was the negotiation of a contract with Honeywell Information Systems, Inc. for the provision of a large Honeywell 6000-series computer facility on which the Multics service will be provided in the future. Complete conversion to this new hardware is scheduled for the spring of 1973; it will provide significant increases in processing speed, disk storage capacity, and number of terminals supportable simultaneously. Unit costs are expected to be reduced by at least 50 percent.

Office of Administrative Information Systems (O.A.I.S.). The O.A.I.S. provides essentially all of the administrative data processing service utilized by the M.I.T. community through the operation of two IBM System/360, Model 30 systems. The first major operational activity of the O.A.I.S. during the year involved the consolidation into a single location of the separate hardware facilities of the two preceding offices and the beginning of the integration of the two staffs. A second activity involved the expansion of the core memory on one of the two installed systems to permit the development of multi-programming systems for the Office, thus significantly improving throughput and efficiency. In addition, unnecessary features were removed from the two hardware configurations with significant cost

savings. A third activity involved recognition that the two Offices that had been joined together to form the O.A.I.S. had sets of standards that were not entirely compatible. A single set of standards is now being developed. A fourth activity for the Office involved initial planning for the installation in November, 1972, of a System/370, Model 135. This hardware was selected to allow the conversion and consolidation of all administrative data processing efforts onto a single hardware system; to permit increases in processing speed and memory size; to permit installation of new input/output devices including remote terminals; to permit continuous evolution of the operating environment; and to improve compatibility with facilities at the I.P.C.

Other Facilities. Service facilities are operated by several M.I.T. departments and research centers to support specialized needs for information processing. These facilities were enhanced during the year with the installation of an additional Digital Equipment Corporation (DEC) PDP-10 at Project MAC to support expanded work of the MATHLAB Project. The Departments of Civil Engineering and Mechanical Engineering developed firm plans to remove their two separate computer service facilities and to replace them with a joint operation providing increased flexibility at reduced total cost.

After this latter change, there will be a total of nine specialized service facilities on campus together with a much larger number of small computers utilized in individual programs of research and instruction.

## Development and Plans

Systems. Under the leadership of the Programming Development Office, an extensive study was undertaken to consider alternative ways of meeting the needs of users of the I.P.C. so as to eliminate, if possible, the chronic problem of operating several facilities no one of which is fully utilized. As a result of this study, the Institute decided to install the IBM Time-Sharing Option (TSO) on an enlarged System/370 facility and to move a large number of the current users of the System/360, Model 67, to that system. There are several major reasons for the selection of this alternative, including increased performance; improved communication between batch and time-sharing users; increased software availability; and reduced cost.

The second major effort for the Programming Development Office this year involved the coordination of plans for the transfer of the Multics system from the current Honeywell 645 hardware to the new Honeywell 6000-series hardware. As the development phase of the Multics project concludes, the P.D.O. staff is increasingly directed towards the provision of enhancements to the Multics system for the M.I.T. community and to the tailoring of the system to match M.I.T.'s specific hardware configuration and its usage.

In addition to these two major tasks, a number of functional enhancements were made to the currently installed versions of several operating systems.

Application and Interfaces for Instruction and Research. In addition to operating computer services, the major function of the I.P.C. is the definition, implementation, and operation of application subsystems, languages, and techniques and the provision of user interfaces to serve the research and instructional components of the M.I.T. community. The developments undertaken by the I.P.C. in this area complement those undertaken by individual users and by the departments. A major task for the coming year is to outline the responsibilities of the I.P.C. and the departments in this area and to produce a coordinated plan for the development of such applications and interfaces.

During the past year, numerous major enhancements were provided to the I.P.C. service environment through increases in the number of software packages and languages available and through expansion of the number of short courses available to users.

Activity of the Student Information Processing Board continued during the year. The role of this student group is to stimulate student interest in computing and facilitate student access to computer services. An increased number of students were involved with the Board this year and services including batch processing and both general and restricted time sharing were offered. Computer terminals were located in a number of living groups.

Application and Interfaces for Administration. During the year the development staff of the O.A.I.S. completed design and installation of new systems to assist the Institute's Payroll, Development, Investment, Personnel, and Alumni Offices. These new systems, several of which represent major efforts, reflect the growing demand for improved and more timely information at all levels of the M.I.T. administration. The rate of introduction of new systems was reduced slightly over the previous year reflecting decreased staff levels in the O.A.I.S.

A major task for the O.A.I.S. in the coming year is the preparation of a complete, integrated plan for the development of information systems to support the administrative offices of the Institute. Two important features of this plan will be, first, the establishment of methods by which the Institute can determine the optimum total level for this development activity, and, second, establishment of procedures to select for implementation the most profitable development projects from all potential projects that can be identified.

### The Future

During the 1972-73 year the information processing services organization is directed towards the following major operational goals: implementation of the TSO system and the successful transfer of the users of the Model 67 to this and other services; implementation of Multics on the new, current-generation hardware; and the installation and full utilization of the System/370, Model 135 facility for the O.A.I.S. Our two major planning objectives are the completion of a comprehensive plan for the development of information systems to support the Institute's administration; and, perhaps most importantly, the identification and selection of ways in which the Institute can significantly improve its abilities to utilize information processing services in its educational programs. Planning efforts in these two areas should lead to implementation activities by the end of the year.

### Personnel Changes

On October 18, 1971, Robert C. Daley was appointed Assistant Director of Information Processing Services and Director of the Programming Development Office. Mr. Daley came to this position following a career involving 11 years as a member of the M.I.T. research staff and, most recently, a senior technical management position within the RCA Corporation. On June 1, 1972, Joseph M. Patten was appointed Assistant Director of Information Processing Services and Director of the Office of Administrative Information Systems. Mr. Patten brings to this position extensive experience in planning and financial management both at M.I.T. and in industry.

ROBERT H. SCOTT

## Joint Center for Urban Studies

New goals had been delineated for the Joint Center before the start of the year. The decision had been made to focus on one major area of concern within the urban field, and housing, broadly understood, had been selected. The administrative structure of the Center was changed to some extent in line with the new research goals, and the housing research program was planned under the direction of a new Joint Center Executive Committee which was composed of faculty members from both Harvard University and M.I.T. Funds for the support of the program were sought, and received, from the two universities and from a group of corporations and other organizations involved in the housing industry and, primarily,

in the manufacture of housing supplies and equipment. Individual projects were funded by specific grants from foundations and government agencies. A Policy Advisory Board was also formed of representatives of the organizations which had agreed to contribute to the Center.

## Housing Research Program

Certain key research topics were pinpointed early in the year, and projects initiated to analyze them. These included the following:

National Housing Goals. It was recognized that the housing goals propounded in the Housing Act of 1968, which called for the construction and major rehabilitation of 26 million housing units over the next ten years, left many important issues out of consideration. The goals focused on new construction and major rehabilitation and neglected maintenance and use of existing stock. Nor were they concerned with the differing needs of different parts of the country. It was felt that a very useful contribution could be made by re-analyzing the 1968 goals, to make them more constructive and realistic. A project was therefore launched which took as its starting point the development of a procedure to measure achievement of the goals, to record changes in the quantity and quality of housing services required, and to estimate future needs both according to geographic area and to type of housing. Initial research in this area was under the general direction of a faculty committee chaired by Professor David Birch of the Harvard Business School.

Work has also been started to identify new combinations of environmental and housing service elements which will describe more adequately the quality of existing housing stocks and will allow a more appropriate measure over time. This work is being undertaken by Alan Dolmatch, a Research Associate at the Joint Center.

Low-Income Housing Subsidies. Subsidies have become accepted as an integral part of any program to provide housing for low-income families. But there is little satisfaction with the effects these subsidies have had on the supply and quality of housing available. Subsidies have generally gone to potential suppliers of new housing, offering them incentives to provide housing for people who cannot afford to pay market rates. Most programs have been considered relatively ineffective in helping the very people for whom they have been intended. An alternative type of program suggested is that of housing allowances, where the subsidy would go directly to the family in need, rather than to a middleman. Such a program would have the obvious theoretical advantage of providing low-income families with the freedom to choose their own housing rather than being limited to specific projects. However, it is not clear how such a program would work in practice, what effects it would have on the supply and quality of housing available, and what problems it would present. A study to analyze the various ramifications of such a program was initiated during the year by Professor Arthur Solomon of the Department of Urban Studies and Planning at M.I.T. and was funded by the Department of Housing and Urban Development. Included in the analysis will be a study of welfare families' experiences in the housing market, since welfare offers one example of a program where the subsidy already goes directly to the family, and an assessment of administrative processes involved in such a program to determine whether they help or hinder the effectiveness of an allowance system. Other faculty members involved in the study are Professors Bernard Frieden, Martin Rein, Joseph Ferreira, all of M.I.T., and Professor David Austin of Brandeis University.

Land Use and Land Development. It is not clear to what extent urban land prices and assembly problems impede the production of new housing. It was felt that research in this area could be most helpful, and an exploratory study was therefore initiated during the spring to analyze the behavior of land prices, particularly of urban sites suitable for construction, and to examine the efficiency of price setting in the market. This initial study concentrated on a review of existing data. It was anticipated that it would lead to a larger research

endeavor during the following year which would consider in more detail questions of public policy and controls, including zoning, the legal problems involved in land acquisition, the exclusionary practices of individual communities, and methods of preparing for future development through such schemes as land banks. Professor Daniel Holland of the Sloan School of Management at M.I.T. and Professor Oliver Oldman of the Harvard Law School undertook the exploratory study.

Other Housing Studies. Several other studies related to housing issues were also launched during the year. One of these is attempting to replicate the evolutionary process of a metropolitan region in some detail on a computer. Such a model of actual development could provide a useful resource for planners wishing to know the quantity and types of housing needs in a community and the call on other related services. This study is under the direction of Professor David Birch of the Harvard Business School.

A grant was received during the year from the Ford Foundation to study the Federal experience with the Model Cities Program. The project is being undertaken by Professor Frieden, Professor Charles Haar (who had been at HUD when the program was launched) and Marshall Kaplan of San Francisco. An examination is being made of the Federal response to both explicit and implicit mandates in the legislation and subsequent administrative developments through a thorough search of the data files and interviews with key participants in the program. It is hoped that the study will yield insights for the design of future urban policies at the Federal level.

A further study, undertaken by Professor Kevin Lynch of the Department of Urban Studies and Planning at M.I.T., started to look at the possibility of preparing environmental quality standards for areas of new urban growth. Emphasis is being placed on the analysis of new formulations of what constitutes residential environmental quality, and more specifically on the development of quality standards for new streets and highways.

A pilot study got under way to design a computer-based manpower information system for the construction industry. Dr. Quinn Mills of the Sloan School at M.I.T. is directing the research which will provide evaluation of the effects of such a system on the operations of the construction labor market, with a view to reducing both unemployment and skill shortages in the industry.

Professor Jerome Rothenberg of the Department of Economics at M.I.T. began during the year to develop an econometric model of metropolitan area housing markets, establishing as distinctive features of the model its ability to measure subjective evaluations of housing quality, its explicit treatment of changes in the quality of the existing stock of housing, and its ability to stimulate the long-run impact of various housing policies.

Professor Lee Rainwater of the Department of Sociology at Harvard and Dr. Richard Coleman, Senior Research Associate at the Joint Center, made a study during the year of existing data on consumer preferences in housing. Among the data sources reviewed for their relevant material have been the two Boston Area Surveys (1969 and 1970) conducted by the Survey Research Program of the Joint Center, the Boston Social Standards Survey (1971), the resources of the Public Opinion Research Center, and the Survey of Economic Opportunity. It is hoped that this will serve as the ground work for a larger study in the future which will aim to develop improved social indicators for housing.

## Other Projects

A report was completed early in the year on a series of workshops on juvenile justice. The purpose of the project had been to devise an effective method for improving communication among the various agencies engaged in the administration of juvenile justice. Three workshops were held in Shirley, Massachusetts, in Hyannis on Cape Cod, and in New York City.

Each drew on a somewhat different universe of corrections officials, others involved in the juvenile justice system, and juvenile offenders. At the workshops, panel groups met for three successive days to discuss the problem of juvenile justice and to delineate suggested solutions. These panels presented an opportunity for all participants to express their individual opinions and to listen to the very varying viewpoints of others involved in the system. In general, it was felt that the experience was worthwhile, and the participants appreciated the opportunity offered for police, lawyers, social workers, even judges and delinquents to meet on an even level of discussion. This project had been under the overall direction of Professor Haar of the Harvard Law School and was undertaken by Dr. Walter Miller, Dr. Thomas Reppetto, and Albert Bottoms.

A report was completed in the spring of 1972 on an analysis of Community Police Patrols. This study undertaken by Professor Gary Marx of the Department of Sociology at Harvard looked at the citizen groups that have sprung up in the last few years to supplement formal police patrols in many communities. It studied their structure, their effects on civil disorder, their place in the community, and the implications for law enforcement and public policy. The study included a survey in the Boston area which disclosed a very high level of support for such groups among the general public. However, it also showed that many citizen groups have difficulty sustaining themselves, and their ability to do so seems to depend in considerable measure on three factors: 1) a continuing crisis; 2) the presence of a charismatic leader; and 3) the emergence of a formally organized structure. The effectiveness of these groups in controlling and reducing crime is questionable. In some cases they seem to have had an effect, in others they have probably not made a difference. But the study indicated that the groups might have another type of value in asserting the power structure of one social/ethnic group in relation to others in a community. Interestingly, little violence seems to have emerged between ethnic groups as a result of these vigilantes; rather they have tended to maintain a defensive character. Yet, the potential for violence is very real and cannot be neglected.

There was an achievement of another kind during the year. Professor Charles Haar of Harvard Law School and Professor Daniel Fessler of the University of California at Davis had in 1970 written a brief of amicus curiae on behalf of the appellants in the case of Hawkins v. Town of Shaw (Mississippi). This brief developed a rationale, based on common law, for requiring that municipalities provide services, such as power and sewerage, on an equal and adequate basis to all residents, whatever their class or color. The court had found in favor of the appellants, however, the Town of Shaw had appealed the case. In the spring of 1972, the higher court upheld the earlier ruling.

An examination was conducted throughout the year of the interrelationship between employment and the receipt of welfare payments. Professor Martin Rein of the Department of Urban Studies and Planning at M.I.T., who is directing the study, has been critically reviewing the service, training, and incentive strategies which have been developed by the Federal government with the hope of encouraging welfare recipients to work.

A major study on family behavior and social policy directed by Professor Lee Rainwater of the Department of Sociology at Harvard continued throughout the year. Professor Rainwater has been examining social problems connected in one way or another with marital and family behavior, and the effects, intended and unintended, of government policies relating to health, legal matters, education, economics, and welfare.

## Survey Research Program

This research facility, which had functioned totally under the auspices of the Joint Center since its formation in 1968, was reorganized at the start of the year. An arrangement was made with the University of Massachusetts to act as a joint sponsor of the program with the Joint Center -- in effect making the program a joint facility of Harvard, M.I.T., and the University of Massachusetts. Administratively, the program was taken over by the state

university and its offices moved to the Boston campus of the university. Directorship of the program was assumed by Dr. Floyd J. Fowler, who had previously been Assistant Director.

### Fellowship Program

The fellowship program was maintained during the year, and eight awards made. Three of these were quite specifically within the research area of housing, and another three in related subjects. The remaining two were in other urban subjects.

### Publications

Three books were published in the Joint Center series of publications during the year: Martin T. Katzman, The Political Economy of Urban Schools (Harvard University Press, 1971); Marvin Lazerson, Origins of the Urban School: Public Education in Massachusetts, 1870-1915 (Harvard University Press, 1971); and George de Menil, Bargaining: Monopoly Power versus Union Power (The M.I.T. Press, 1972).

One monograph was also issued by the Survey Research Program of the Joint Center and the University of Massachusetts in conjunction with the Medical Foundation. This was entitled Use of Health Care Services in Greater Boston (1972).

The Joint Center launched two new series of publications during the year. The first consists of Working Papers representing reports by Joint Center members of ongoing or unpublished research; the second consists of Abstracts of masters and doctoral dissertations on housing issues that have been completed at Harvard and M.I.T. Nine Working Papers were issued during the year. The first seven of these represented a summary report by the Director, Professor Bernard Frieden, and six background papers on Federal housing subsidies; these had been prepared for the Subcommittee on Housing of the House of Representatives Committee on Banking and Currency in 1971. Only the summary by Professor Frieden had appeared in the Committee report. The six background papers were written by Victor Bach, Lisa Peattie, Martin Rein, Arthur Solomon, David Stern, and James Wallace, all of M.I.T. The other two Working Papers were written by Professor Lee Rainwater of the Department of Sociology at Harvard. Their titles are "Public Responses to Low Income Policies: FAP and Welfare" and "An Exploratory Study of a Social Psychological Metric for Magnitudes of Poverty."

The Abstracts series included ten reports, representing studies completed during 1969 to 1971.

BERNARD J. FRIEDEN

## Laboratory for Nuclear Science

### Experimental Nuclear and High-Energy Physics

Our broad and varied program in low, medium, and high-energy nuclear and particle physics continues to be vigorous, despite restrictions resulting from continuing budgetary curtailments. Our low-energy program continues to develop its main theses: exploration of the symbiotic possibiliities of using the dynamic features of nuclear transitions inside solid matter to study the nature of the magnetic and electric fields inside solids and to derive the electric and magnetic structure of nuclei in excited, short-lived states; use of our multiple-gap nuclear spectrograph in conjunction with the double tandem generator at the Brookhaven National Laboratory to study the highly excited, short-lived, high-spin states of light and medium nuclei through the analysis of the nuclear products of heavy ion collision; study of the atomic structure of highly ionized atoms through the X-ray spectra induced in ion-ion collisions; study of the structure of nuclei near closed shells by investigation of their (unex-

pectedly complex) spectra through nuclear excitation by $\alpha$-particles.

In the medium-energy range, we can report with pride and pleasure the successful operation of our electron linear accelerator at Middleton, Massachusetts on December 23, 1971; the first beam of energy greater than 100 million electron volts (our destination is 400 MeV) was achieved on April 4, 1972, just three days before the official opening of the installation and its dedication in the memory of the late Representative William H. Bates. Our medium-energy group is concentrating on the preparation of the accelerator's experimental facilities, in close cooperation with a newly organized national users group, while phasing out its program of using electron and photon scattering (at the 100MeV electron accelerator of the National Bureau of Standards) to study the charge distributions and shape functions of the ground and excited states of a number of light and medium-weight nuclei.

In the high-energy range, our groups are involved in research at all operating accelerators, including the Deutsches Electron Synchrotron in Hamburg, Germany, and the proton sychrotron and its intersection storage rings at the European Center for Nuclear Research in Geneva, Switzerland. We are also working on two of the accepted experiments at the National Accelerator Laboratory in Batavia, Illinois, just now coming into operation in the 200-500 billion electron volt energy range. During the past year our experiments on the "deep-inelastic" scattering of electrons on protons, which first exhibited the exciting new phenomenon of "scaling" in high-energy interactions among the so-called elementary particles, have been extended to the scattering of electrons on neutrons, with the interesting and puzzling observation that, while also exhibiting the "scaling" property, the electron-neutron scattering is considerably weaker than electron-proton scattering; these results provide a rather stringent test for the models that have been developed to "explain" our earlier electron-proton scattering data.

Other high-energy experiments involve the investigation of hadrons (strongly interactive nuclear particles) by electromagnetic radiation, at the Cambridge Electron Accelerator, the Deutsches Electron Synchrotron and the Stanford Linear Accelerator Center, the study of the production of neutral products in the interactions of charged pi-mesons and anti-protons with protons at the Brookhaven National Laboratory, the Argonne National Laboratory, and the Stanford Linear Accelerator, and the detailed investigation of the so-called vector dominance model as applied to the conversion of electromagnetic radiation into elementary particles. Our bubble chamber group has developed an important new technique for the study of many-particle production in elementary particle reactions, through use of a new process of analysis -- the prism plot. This new analysis technique gives promise of permitting the complete identification of the dynamical features of extremely complex interactions among elementary particles involving up to five or six product particles.

## Nuclear and Particle Theory

Our Center for Theoretical Physics continues to serve, also, as a center for the interchange of ideas and techniques between nuclear and particle physicists, as well as a center for the close collaboration between theoretical and experimental physicists. Thus, one of the most interesting recent developments was the application of ideas concerning collective excitations in nuclei to the description of the highly excited, high-spin states observed in experiments on nucleus-nucleus interactions. Progress has also been made in the application of theories of nuclear matter to the actualities of finite nuclei. New and more sensitive techniques have been developed for the analysis of scattering of nucleons and electrons from complex nuclei in the intermediate-energy range; one result has been to demonstrate that the widely held belief, that nuclear charge densities decrease near the nuclear center, has no experimental basis.

Work has also continued in application of the Veneziano model in inclusive reactions, and on problems of duality and scaling in hadronic interactions. One interesting new result has been

an indication that Regge models are not consistent with scaling in the high-energy limit. But perhaps the most exciting new result arises from an old one, in the demonstration that Weinberg's field theoretic, unified formulation of the electromagnetic and weak interactions, first published several years ago, is renormalizable and can provide a basis for the description of the observed properties of the weak interactions. Much effort is now being devoted to the computation of observable consequences that could serve in a critical confrontation between the theory and experiment.

The above is just a small sampling of a very large spectrum of theoretical work which resulted in a very large number of publications this year.

### Population Statistics

Participants in the work during the past year totaled approximately 350 persons. This number includes 52 academic staff members, 91 graduate students from the Department of Physics, 35 research staff members at the post Ph.D. level and 174 employees in supporting categories (engineers, technicians, machinists, administrative, computational, etc.). A total of 26 Ph.D. degrees, 3 Master's degrees and 18 Bachelor's degrees were completed during this period by students engaged in thesis research in physics within the laboratory.

Financial support is derived mainly from a contract with the Atomic Energy Commission. An approximate breakdown of the relative annual support in various areas is as follows (based on FY72 figures): for expenses of the operational type (salaries, wages, employee benefits, materials, services, travel, etc.), approximately $2,650,000 for studies, both experimental and theoretical, in high-energy physics; $800,000 for medium-energy physics largely associated with the pre-operations phase of the 400 MeV Linac facility at Middleton, and $750,000 for low-energy theory and experiment. Equipment funding under the AEC program during this period totaled $495,000 broken down as follows: $70,000 for high-energy physics; $400,000 for medium-energy, and $25,000 for low-energy physics.

PETER T. DEMOS

## Libraries

In this, my final report as Director of Libraries, it seems appropriate to look back over the 16 years since I was asked by President Killian to take on this responsibility. During this period sweeping changes in the Libraries have reflected equally sweeping changes in the Institute: four presidents, 14 years of expansion, two years of retrenchment.

When I became Director it was clear that the Libraries were in the doldrums. After a spurt in the late 1940's when the Hayden Library was built, they had lost momentum. The administrative structure, under which the Director reported to the Dean of Humanities, did not correspond to the Institute-wide responsibilities of the Libraries. The Libraries were being run by a Faculty committee and, except for the Hayden Building, the physical plant was deplorable.

The situation was nearly ideal for a new Director. The Faculty Committee reassumed its advisory role; the budget improved, as well as the physical plant. The Table shows a number of key figures at five year intervals.

Now the picture has changed again. After two years of cuts in staff and in appropriations for books and journals and with another hard year to come, there is a question as to whether the Institute can maintain libraries adequate to support its reputation as one of the world's outstanding universities. The Report of the Ad Hoc Committee on the Libraries, under the Chairmanship of Dean Robert A. Alberty says, "In the future the Libraries will have to accept the responsibility for limiting their growth, while at the same time meeting the needs

Figures for the M.I.T. Libraries at Five Year Intervals

| | 1955-56 | 1960-61 | 1965-66 | 1970-71 | 1971-72 |
|---|---|---|---|---|---|
| Volumes in Libraries | 588,835 | 745,767 | 900,468 | 1,314,070 | 1,383,492 |
| Journal Titles | 2,717 | 2,751 | 4,343 | 6,841 | 7,237 |
| Volumes Loaned | 168,577 | 230,088 | 224,510 | 382,849 | 380,860 |
| Seating Capacity | * | 1,036 | 1,788 | 1,879 | 1,879 |
| Square Footage | 103,410 | 110,600 | 144,430 | 175,314 | 175,314 |
| Professional Staff | 24 | 33 | 60 | 62 | 57 |
| Support Staff | 36 | 54 | 110 | 158 | 153 |
| Student Staff (FTE) | 9 | 12 | 20 | 20 | 24 |
| Expenditures | | | | | |
| Materials (books, serials, journals) | 74,825 | 113,049 | 413,061 | 679,698 | 712,186** |
| Salaries | 196,274 | 370,423 | 873,164 | 1,441,944 | 1,551,588** |
| Other | 10,764 | 40,485 | 56,172 | 190,839 | 143,615** |

*Not available

**Budget figures

of the community." Like committees at many other schools they see little chance of more money or more space. Computers cost more rather than less. Faculty and students of the future will have to go elsewhere for low-use materials. The Committee concludes, "In order to provide access to all the information needed by this community, the M. I. T. Library has to cooperate with other libraries and in the future, hopefully, with new types of national or regional libraries."

Perhaps the time has come at last when the advantages of broad cooperation among universities for library development can be seen to outweigh the disadvantages. I plan to devote a substantial fraction of my time in the next few years to an investigation of these possibilities.

In closing I would like to say a word of appreciation to the Heads of the various libraries and library departments and all the professional and support staff who have been here as long as 35 years, or as little as 5 days. The quality of any organization depends on the quality of its people. The growth in excellence of the M. I. T. Libraries over the last sixteen years has been brought about by several hundred individuals to whom the whole Institute owes its gratitude. Above all, my sincere thanks to the leadership group of exceptionally loyal and gifted Associate and Assistant Directors with whom it has been my privilege to work during these years. They have contributed fully to the making of the superior library system which the Institute now has.

## The Evolution of the M.I.T. Libraries

This brief survey will take up in turn the School Libraries and their branches, the Student Center Library, the Technical Services Departments, the Archives and the Computer Applications Division. Each has expanded, some remarkably, in the last 16 years.

### SCHOOL LIBRARIES

*Architecture and Planning*

The Rotch Library of the School of Architecture and Planning has fared least well of the School Libraries in its physical setup, mainly because its space problems are part of those of the whole School. In 1965-66 some 40 percent additional space was added on the floor below with an interior staircase but the library has been neither carpeted nor air-conditioned as have all the other School Libraries since the 1940's, and it is completely full again. Its budget has improved greatly in recent years, but it still has a long way to go if it is to build its present spotty collections into solid support for the rapidly growing interests of the School. The overlap of teaching and research between Urban Studies and Planning on the one hand and Political Science and Economics on the other, not to mention Civil Engineering, raises the question of serious and growing duplication. There is one obvious move which would maximize faculty, student, and research productivity, along with supporting library services. It would be to bring together in one geographical location all those working on urban problems along with their libraries.

Rotch probably has the best rapport with the faculty and students of all the School Libraries, probably because of an awareness of shared problems. The Librarian has been invited to faculty meetings; the library committee and the Dean are actively supportive of library needs. In this School, as elsewhere in the Institute, there are two groups, the historians for whom the library is the main resource for research, and others for whom current materials have priority and speed of delivery is the prime essential. The Alberty Committee and Project Intrex have emphasized services to the latter, to the practical exclusion of the former.

*Engineering*

For the last six years the Barker Library, renamed for James M. Barker, Class of 1907, who generously supported the modernization of the old Engineering Library, has enjoyed separate status. This came about as a result of Project Intrex, which needed a library in

which to conduct its experiments. It has been beautifully remodelled after having been badly neglected for many years. Intrex can always point with pride to the Barker Library as a concrete result of its efforts.

At first the Engineering Library had only one branch, Aeronautics and Astronautics. This has undergone a number of face liftings and expansions. Though not air-conditioned it is otherwise comfortable and well suited to its work. Two other small branches have been added, the Materials Center Reading Room, when the Bush Building was built and the Space Center Reading Room in the Space Center. Both opened in 1965. These special purpose reading rooms are convenient, inexpensive to staff, and are paid for partly or entirely from project funds. Their materials are mostly duplicated in the Barker Library, though budget cuts are changing this.

The Barker Library has fared well in money for materials and far better in staff than the rest of the Libraries. This has been particularly clear in the last three years of budget cuts.

*Humanities*

The Humanities Library serves only two of the departments of the School, the Department of Foreign Literatures and Linguistics and the Department of Humanities. Probably the latter is the least well served of any Department of the Institute. In spite of occasional individuals, faculty and students, who care, one cannot escape the impression that the Department as a whole does not. Frances B. B. Summer, Humanities Librarian, has noted that the most vital task for the libraries in 1972-73 must be evaluation and shaping of the collections, and programs, and the redefinition of goals. These are clichéd phrases which must be translated into written book selection policies, fruitful conferences with faculty and with other divisional librarians, decisions about weeding and reclassification of monographs, rigorous scrutiny of journal and serial holdings.

The physical facilities are adequate for the present. The reading room is rarely full and the stack space in the basement of the Hayden Building will allow for three or four years of growth. Book purchase funds in the operating budget have met expressed needs. Occasional special appropriations have been made for a new curriculum like philosophy or where a special opportunity arose to fill a gap, as in linguistics or Russian literature.

The Humanities Library staff has a number of responsibilities beside building the collections and servicing them. They operate the Music Library, the small Reserve Book Room in the Hayden Building and the Rare Book Room. They answer questions about the Institute libraries and their holdings, borrow books from other libraries for our people (up 10 percent) this year, and loan books from M. I. T. to other libraries (down 10 percent). For a number of years they were responsible for relations with non-M. I. T. users, issuing library cards and running the Membership Plan for Industry, under which an average of some thirty companies buy blocks of library cards for their staff, but these "extramural" services have now been shifted to the Assistant Director for Reader Services.

The Music Library is in difficult straits. It is not able to expand physically, hemmed in as it is between the shipping room on one side and the Science Library on the other. It has undergone several renovations, adding to space for shelving books, records and tapes, but reducing the number of seats for concerts. It is also now in its third generation of electronic recording and playback equipment. Large increases in music subjects (enrollment of 296 in 1959-60, 826 in 1971-72) now strain every aspect of the facility. There seems to be no long-term solution for Music except moving to some larger location, preferably in conjunction with a move of the Music faculty.

The Reserve Book Room illustrates a dilemma that affects the Student Center Library and the reserve book collections in all the School Libraries. The trouble is that the Faculty ask

for so many books to be put on reserve, only about half of which are ever used. They have to be bought; they take a lot of work; and they take up space -- all of which is wasted. Moreover, some faculty members fail to notify the Libraries in time what books they want put on reserve. The Alberty Committee suggested a campaign to increase faculty understanding of the reserve book question and individual librarians have started work in this direction.

The Rare Book Room has been cleaned, humidified, and its air intake equipped with filters; its security has been improved by welding shut a door which has apparently served as an entry for thieves, and by installing an alarm system. The collection of notable works from the past was augmented this year by a leaf from the Gutenberg Bible, gift of Edward Davis, Class of 1901, which incidentally provides a striking illustration of the inflation in the value of rare books. The donor bought it some 50 years ago for $10. Recently a perfect leaf is said to have fetched $2,000 at auction.

At a reception in June I. Austin Kelly III, Class of 1923, announced that he is planning to give to the Institute in honor of the retiring Director of Libraries his collection of first editions of some of the rarest and most important books in the history of human thought. This is a splendid gift deeply appreciated by the Director. The Institute for its part should provide a safer place to store its many fine rare books and an attractive area to make them accessible to the community.

*Dewey Library*

The most striking growth rate of any library in the system has been achieved by Dewey, which services the School of Management and the Departments of Economics and Political Science of the School of Humanities. Sixteen years ago it occupied a small area on the third floor of the Sloan Building. It was remodelled and expanded twice in that location before it was able to move in 1965 to the new Hermann Building where the first floor and parts of the basement and the second floor had been designed for it. Since then it has expanded into two of the classrooms on the second floor and plans are under way to add the rest and more of the basement.

The Dewey Library has been built up so rapidly that most of its collections are recent. Little can be discarded. The growth has been slowed down by budget cuts, for instance a recent reduction of $5,000 for journals and serials, but it must grow or die. For fields like political science and economics the library is the laboratory. Eventually it will have to take over all the Hermann Building or move somewhere else, preferably, as mentioned above, in conjunction with the collections in Urban Studies and Planning.

In these 16 years the Dewey operating budget has grown rapidly, not to mention an invaluable $50,000 a year for five years from the Ford International Relations Grant. This grant permitted us to bring in a qualified literature specialist to work with the faculty on the selection of books and periodicals, thus improving both the quality and quantity of our purchases in international relations.

Quality has been the principle followed by Barbara Klingenhagen, librarian of the Dewey Library since it was started 25 years ago in Building 5. She has also been preeminent among the professional librarians for working closely with faculty and students to make the library an integral part of the process of education and research. She retired at the end of 1971 and Edgar Davy, her successor, has already taken a number of steps to continue this policy and to work out cooperative collecting policies with the Business School and the Industrial Relations Libraries at Harvard.

*Science Library*

Like Humanities, the Science Library has remained comfortably in the Hayden Building

during this period with new lights, a new sound-absorbant ceiling and rug to make it a pleasanter, quieter place to work. In the early years it became badly crowded with students from neighboring schools using it as a study hall -- so crowded and noisy that it was difficult to do any serious work. Two steps were taken: a book checker was hired to assure that books leaving the library were checked out and that people coming in at busy times belonged at the Institute; also, a partition was erected to create a separate lobby where noisy activities like book borrowing, book checking, and copying could be done. Even after this there were too many undergraduates using our libraries as a study hall. This was solved six years ago with the opening of the Student Center Library, for which see below.

Sharing the storage area in the basement of the building with Humanities, Science can continue to grow for three or four years. Its growth rate averages only three percent a year because it is mostly a mature library in non-verbal fields. One area of pronounced growth, however, has been the biomedical field, reflecting an Institute-wide trend. Fortunately the Countway Library, a regional medical library operated by the Harvard Medical School, has provided valuable backup for us. In 1958 reciprocal privileges were agreed upon and in that first year 20 cards were issued to M. I. T. people. This was up to 97 in 1969, 382 in 1972. At first the Harvard people used the Science Library almost as much as M. I. T. people used the Countway, but now the Countway has bought more heavily in the basic sciences so their use of the Science Library has fallen off. This indicates one of the difficulties in maintaining cooperation between libraries. It is easy and fruitful between equals, each of whom has something to offer to the other. When one is much stronger, and the traffic becomes all one way, then some way has to be found to reimburse the strong library for services offered to the weak library. The principle that state and Federal funds can provide this reimbursement seems to be receiving acceptance. Perhaps the regional medical library pattern will be followed for other fields.

Since budget cuts, the absence of selection policies for the libraries is keenly felt. The Science Librarian, Irma Johnson, has noted that if the goal cannot be excellence for all research areas, the libraries must know what fields should be collected at what levels. The recommendation of the Alberty Committee that such policies be developed should have the highest priority. They will provide a more efficient, more coherent system.

In the 1950's the earth sciences collections were in the Science Library, having been amalgamated with those of the physical and life sciences to form the Science Library in 1952. With the opening of the Green Building in 1964, the earth sciences collections were moved to the third floor which has been beautifully designed as the Lindgren Library. This is the most attractive branch library. Working relations with the faculty have been excellent, too, and the funds have been sufficient to maintain quality while adding oceanography and some aspects of space science.

Two other branches of the Science Library have been opened recently, one for chemistry, one for physics. The Captain John Baptiste Ford Chemistry Reading Room in the new Dreyfus Building, was planned as an experiment in the use of microfilm. Back issues of 56 journals were purchased on cassettes to be used with Recordak readers and reader-printers. Only reference books and current issues of journals were to be on paper, with the latter put on film at the end of each year. This experiment has had moderate success, having been delayed by difficulty in procuring filmed journals -- after two years not all runs are complete -- and by much higher cost for the film and readers than anticipated. The original estimate was that it would cost less to set up and no more to operate than a conventional reading room. In fact, the setup costs were less, as was the space required, but operating costs are at least twice as much. Some of the chemists find journals on film -- especially abstract journals -- convenient for literature searching, but poor quality commercial filming, higher prices, and poor optical and mechanical design of readers and reader-printers are discouraging. Fortunately, all titles are also available on paper in the Science Library, 50 yards away.

The Physics Reading Room was opened in the fall of 1969 after cooperative planning by the Department of Physics and the Library staff. It was operated for two years by the Libraries, but a series of unfortunate circumstances, partly due to human failure on the part of the Libraries and partly because the Department wanted to run it in the first place, resulted in the Reading Room being taken over by the Department in 1971.

The $25,000-30,000 a year expense of Chemistry and Physics Reading Rooms which duplicate the Science collections has to be looked upon as the marginal cost of providing a specialized reading room where faculty and students can work together in congenial surroundings.

One final responsibility of the Science Librarian is running the loan desk for the Humanities and Science Libraries. Loans are up 20 percent this year over last and the other libraries of the system also show loans up 10 percent or more. Just why library use should go up when the Institute population is decreasing is an enigma the answer to which would be helpful for future planning.

*Student Center Library*

The only major new facility in recent years is the Student Center Reading Room, which opened in December, 1956, and nearly 2 1/2 million people have been checked in since then. It occupies the top floor of the Student Center where some 25,000 net square feet are devoted to 500 seats and 15,000 reserve books for all the Courses at the Institute, both graduate and undergraduate. Active planning started only after the construction of the building was under way because for a long time the Student Center Committee felt that the top floor should be saved for later expansion for student activities. They finally became convinced, however, that the convenience of having a reserve book reading room open 24 hours a day, seven days a week was too great to be turned down. Its popularity proves that they were right. It is busy all day and busier in the evening. Even at 3 a.m. there is an average of 35 people in the library.

Weekly attendance this year varied from 11,029 the week of December 6-12 before exams to 1,218 during Christmas vacation. Total attendance this year was down 8 percent from last year, perhaps because new and remodelled dormitories make it easier to study there. The lower attendance did not visibly affect the abuse of the furniture or the stealing of students' personal property.

The Student Center Library is a victim of its own success. It is so big and so busy that it is neither as quiet nor as clean as it should be, but it is still extemely popular.

## TECHNICAL SERVICES

Half of the work of a library takes place behind the scenes, out of sight of the public. There are three departments whose work is proportional to the flow of new books, Acquisitions, Cataloging, Serials and Journals; two more which operate in a special medium, the Microreproduction Laboratory and the Computer Applications Division.

*Acquisitions*

The Table at the beginning of this report, shows the rapid growth in the number of volumes over the years. Receipts are up 18 percent this year. Each item has to be ordered, received, checked for correctness, followed up if not received, paid for. Obviously, these activities are candidates for automation and Acquisitions has been working with the Computer Applications Division for five years to bring this about. At last in the past year the libraries have had almost monthly in-process status reports and have completed negotiations with the Comptroller to accept the printout of invoices approved for payment. Ultimately the Comptroller will bypass the printout and will print checks on the basis of tape. This year also the libraries are beginning to keep processing and financial statistics by computer. The long

delays and the unreliability of the computer process are frustrating in the extreme.

*Cataloging*

The Catalog Department, like Acquisitions, has suffered from crowding and poor temperature control. Nevertheless, they have continued to produce high quality cataloging. As the volume of books has gone up, the department has been divided so that one section handles books which have not been cataloged by the Library of Congress; the other section is able to provide simplified, rapid handling where an L. C. card is available. Subscription two years ago to the MCR Service on microfiche which provides copy for all L. C. cards has been a boon and has more than paid for itself out of savings.

The Libraries are not so fortunate with the computer. A number of systems are available for the production of catalog cards by computer. The Department has been eager to move but the alternatives have been studied so carefully that a decision is still in abeyance, with resulting morale problems. It should be added that all computerized methods are more expensive than manual ones and there has not been and still is not any visible source of extra funds. One of the best systems, operated by the Ohio College Library Center, is estimated to cost an additional $35,000-40,000 the first year. The cost in later years cannot be predicted. Another excellent system but slightly more expensive, is operated by a local Massachusetts firm. A third has been announced, looks good in some ways, but is not yet operational. With such systems, books could get onto the shelves and cards into the catalogs faster. That is a real advantage. But can the Libraries afford it? The Libraries have joined the New England Library Network, a part of the New England Board of Higher Education, and regional representative of the OCLC, but only as "sustaining members" until the situation with respect to money for meeting costs becomes clearer.

The Head of the Catalog Department, Frances Needleman, expresses the result of five years, noting that it has become increasingly apparent that in order to have mutual professional expertise, it behooves librarians to analyze their individual operations; learn more about computer technology; know what the computer can do to improve their operations, without letting their imagination be limited by lack of knowledge of the computer's capabilities; and convey their needs in the best informed manner.

*Serials and Journals*

Sharing with the previous two departments in the physical problems of the room they occupy, Serials and Journals has had the same morale difficulties. This department shares also the frustrations of Cataloging with relation to computerized operations but with a difference. While automating the tedious operation of checking in serials publications is still ahead, the Libraries are in the fourteenth year of a computer produced list of the serials and journal holdings of the M.I.T. Libraries. M.I.T.'s was one of the first in the country but whereas in the first few years it was printed from punched cards within 30 days of the time the record was closed, it takes over six months now that we have modern on-line editing and computer composition. Of course, it is far more attractively printed now but it would be nice some day to get back to a 30-day production schedule.

*Microreproduction Laboratory*

Over the years the laboratory has grown to keep pace with orders for copies of materials in the library from industry and government as well as from the Institute. Orders from industry were down 30 percent this year but government orders were up 50 percent. Quick copies (SCM) were up 8 percent to 923,000; prints made by other processes were roughly comparable in number; and nearly half a million catalog cards were produced.

It is a curious fact that the Microreproduction Laboratory was set up at M.I.T. 25 years ago when microfilm seemed certain to replace books in a few years. It has not happened yet and it is not going to happen soon, though microforms are making some progress. Micro-

fiche took a step forward this year when the Graduate Policy Committee was persuaded by the Graduate Student Council to change the thesis requirements so that the archival copy will henceforth be on microfiche rather than carefully typed on acid free paper.

For the Laboratory the decision means a new source of income. For the Archives and the rest of the libraries it means more work and more space now but in theory the paper copies can eventually be thrown away and only fiches retained.

ARCHIVES

The Institute Archives were set up with a staff in 1960. Six years later Professor E. Neal Hartley of the Department of Humanities joined as part-time Institute Archivist. Since then he and his staff have made fine progress in publicizing the existence and the goals of the Archives, in collecting records, reports, and memorabilia and in organizing exhibits. The two most ambitious exhibits are the recent Retrospect, organized in cooperation with the Department of Humanities for President Wiesner's inauguration, and Retrospect II, prepared in cooperation with the Committee for Institute Memorabilia for Commencement and Alumni Day this year.

COMPUTER APPLICATIONS DIVISION

This division of the Libraries was started ten years ago as the Technical Information Project, when its Head, Dr. Myer M. Kessler, came to the Libraries from the Lincoln Laboratory where he had been working on a physics information system. This system matured and has been taken over by the American Institute of Physics. Oversimplifying one could say that Dr. Kessler then turned his attention to library problems. In fact it was merely a shift of emphasis. The basic computer systems were general enough to be applied to most library activities. In the last few years a number of subsystems of a computerized inventory control system for the Libraries have become operational.

Shortages of money and of computer time, threats of changes and actual changes in hardware, and uncertain administrative support have contributed to a gradual weakening of morale in the computer division and among the members of the library staff affected by the computer or who wanted to work with the computer.

As usual, money is the key. After the grants stopped the Institute has been undecided for over a year as to whether it should support the development of its own system. Very likely it should not. It is a matter of scale. M.I.T. is probably of sub-critical size. The Information Systems Panel of the Computer Science and Engineering Board of the National Academy of Sciences in an outstanding 1972 report, Libraries and Information Technology, writes, "... only a few of the larger libraries can justify the expense of independent local automation. Alternative approaches are being developed by creating service agencies to provide automated programs for consortia, or regional groups of libraries such as those in Ohio, New England, and California."

It is the best guess of the retiring Director of Libraries, that the services we need could be purchased for $50,000-75,000 a year rather than developed locally at twice the cost.

## Professional Staff Activities

Jacqueline Colby served as President of the New England Technical Services Librarians and as Section Representative to the New England Library Association.

Reay Freve is a member of the Boston Architectural Center Library Committee.

Myer Kessler serves on the Cambridge Project Policy Advisory Group, on the M.I.T.

Information Processing Center Advisory Board, and is a consultant to the American Council of Learned Societies for the Research and Development Project in Automated Bibliography.

William N. Locke continued as Chairman of the following Committees: Linguistics in Documentation (International Federation for Documentation); Membership (Association of Research Libraries); and Constitution and Bylaws (American Society for Information Science). He also continued as Delegate of the New England Foreign Language Association to the National Federation of Modern Language Teachers Associations and as Liaison Officer of the American Society for Information Science to the American Council of Learned Societies.

Sylvia McDowell was a member of the Planning Committee for Project Interphase for 1972. She was a Freshman Advisor and a member of the Women's Forum.

Frances Needleman continued as Secretary of the Executive Committee, Cataloging and Classification Section, Resources and Technical Services Division, American Library Association.

Natalie N. Nicholson was a member of the 1972 Information and Hospitality Committee of the Boston Chapter of the Special Libraries Association. She continued as a member of the ACRL Committee on Standards and Accreditation and the Urban Universities Library Committee of the American Library Association. She also continued as a member of the Boston Joint Program for Minority Group Recruitment to Librarianship.

Margaret Otto served on the Committee on Public Relation Services to Libraries of the American Library Association Library Administration Division.

Peter Scott continued as Chairman of the American National Standards Institute Committee PH5-2 on Microfiche and Micro-Opaques and as a member of the PH5 Committee on Document Reproduction and of the PH5-1 Committee on Microtransparencies. He served on the Executive Board of the New England Microfilm Association. He was Chairman of the Information Retrieval Committee of the National Microfilm Association and a member of the Board of Fellows of the National Microfilm Association.

## Staff Changes

*Appointments*

The following appointments were made during the year: Katharine G. Cipolla, Head, Serials Acquisitions Section; Edgar W. Davy, Dewey Librarian; Ann M. DeVilliers, Assistant Science Librarian; Myriel C. Eykamp, Assistant Science Librarian; Randolph E. Hock, Assistant Science Librarian; Helen L. Mitchell, Serials Cataloger; Deena M. Pers, Cataloger; Jutta R. Reed, Associate Humanities Librarian; Cheryl Ann Reuter, Assistant Dewey Librarian, Heddy Ann Richter, Assistant Humanities Librarian; Susan R. Stevick, Assistant Humanities Librarian; Nancy G. Vaupel, Assistant Humanities Librarian.

*Promotions, Leave, Return from Leave, Transfers, and Retirements*

The following staff changes were effected during the year: Margaret E. Depopolo, Associate Rotch Librarian; Barbara Klingenhagen, Dewey Librarian, Retired; William N. Locke, became Director Emeritus; Suanne W. Muehlner, Lindgren Librarian, returned from leave; Arthuree R. McLaughlin, Senior Assistant Science Librarian; Frances B.B. Summer, Humanities Librarian.

*Resignations*

The following resignations were received during the year: Karl S. Bynoe, Humanities Librarian and Head, Extramural Services; Ching-chih Chen, Associate Science Librarian; Joseph M. Dagnese, Assistant Director for Technical Services; Barbara F. Frick, Assistant

Science Librarian; Linda Fuerle, Assistant Humanities Librarian; Valda V. Maeda, Slide Librarian; Maureen J. Malone, Assistant Humanities Librarian; Tovah Markowitz, Head, Serials Acquisitions Section; Nancy J. Prolman, Cataloger; Astrid H. Steele, Associate Science Librarian; Judith Walpole, Assistant Dewey Librarian.

WILLIAM N. LOCKE

## Northeast Radio Observatory Corporation (NEROC)

M. I. T. is a leading member of NEROC, a consortium of 13 educational and research institutions formed to promote radio and radar astronomy research. Through a NEROC-M. I. T. agreement, the administrative services of M. I. T. are used by NEROC in the conduct of its business.

The largest current responsibility of NEROC is the operation of the Haystack Observatory at Westford, Massachusetts. Haystack's 120-foot antenna, operable over a wavelength region from 21 to less than 0. 8cm, is currently used some 5000 hours/year for radio astronomy and 800-1000 hours/year for studies of the moon, Mars, Venus and Mercury with the 3. 8cm planetary radar system. NSF grants largely support the radio astronomy work, while the radar work is mainly supported by NASA. As of early this year, 18 radio observing programs were in progress, involving 11 students and 25 faculty and staff members from 15 institutions. The radar work is conducted by Haystack and M. I. T. workers. The observatory is also vital to the radio astronomy research carried out by faculty and students in three departments at M. I. T.

Haystack has figured in pioneering experiments in very long baseline interferometry (VLBI), a technique based upon precise frequency/time standards which makes possible interferometer baselines of thousands of kilometers. Using this technique between Haystack and a large telescope in the Crimea, observations on a galactic maser source were obtained with an angular resolution of 0. 0003 arc seconds -- the highest resolution ever achieved in astronomy. High-resolution single-antenna mapping, and spectral line studies over a broad range of relatively short wavelengths are also being emphasized.

Investigators working at Haystack have detected and confirmed five new sources of water-vapor radiation associated with long-period variable stars.

The radar has made possible topographic charting of the visible lunar surface with height resolution of the order of several hundred meters. Topographic charting of the equatorial regions of Mars is also being carried out to assist NASA in planning for the Viking landing missions planned for 1975.

Aside from the operation of Haystack, NEROC has an ARPA-funded contract with the Aeronautical Chart and Information Center for the development of VLBI as a precise geodetic measuring technique. Baseline measurements to a few meters accuracy have already been made over distances of nearly a thousand kilometers.

PAUL B. SEBRING

## Operations Research Center

The Operations Research Center brings together faculty and students from various M. I. T. departments to conduct an academic program and do research on the underlying methods and practical applications of operations research.

The interdepartmental Ph. D. and S. M. programs continue to provide Institute-wide coordina-

tion for graduate education in the field. The past year has seen a substantial growth in student interest. This appears to be the result of 1) an increasing recognition of the importance of the operational and systems aspects of engineering and social problems; 2) the weakening job market for science and engineering skills per se; and 3) a desire on the part of students for a field that demands high technical skill and at the same time is potentially socially useful. Students presently affiliated with the program come from more than a dozen different departments and substantial numbers of students are now applying to M. I. T. from outside.

During 1971-72, the major research activities of the Center's faculty and students have been in the areas of basic mathematical methods, transportation science, and public systems. Work in mathematical methods has had two main thrusts. The first, in optimization, has centered on integer programming, mixed integer programming, and the optimization of large time-dependent systems. In integer programming a special emphasis has been placed on computational methods that are based on the group theoretic approach and on combining integer programming theory with duality theory. A second theoretical area has been decision analysis and utility theory. Work has progressed on the decomposition of multi-attribute utility functions, Bayesian econometrics, and the conduct of decision analyses in circumstances when it is desired to incorporate the preferences of groups rather than a single individual.

Research in transportation has evolved in a variety of directions. Topics studied have included air traffic control in the terminal area, automated ground transportation traffic signal control in street networks, the reliability of rail freight shipments, routing decisions for bus systems, airline crew scheduling, and automobile insurance operations.

A substantial effort has gone into non-transportation public systems. A major project has been completed on citizen feedback. This work has been concerned with the quality and timeliness of state-government response to citizen communications and the use of information thereby generated to affect governmental operations. In addition, in order to facilitate citizen-to-citizen and citizen-to-government communications, technological aids have been developed to improve the effectiveness of group meetings. Another important research area of the Center has been urban service systems. In particular, the commonality among emergency service operations such as fire, police, and ambulance services has been exploited to develop a body of theory for location of facilities and allocation of effort. Other public systems problems under study include various aspects of the criminal justice system, blood banking, water resources, solid waste disposal, and library operations.

More detail on these studies is available in the Center's Annual Report and reports on specific projects.

Support for the Center's research has come from varied sources, including National Science Foundation, the Massachusetts Department of Education, the Public Health Service, General Motors, the Office of Naval Research, the Army Research Office-Durham, and the Mobil Oil Corporation.

JOHN D. C. LITTLE

## Project INTREX

In 1966, Project Intrex began to investigate new ways of providing information to users of large libraries. Research and development activities have been carried out in the Electronic Systems Laboratory and, since 1970 the James Madison Barker Engineering Library has been the location for closely monitored user experiments. These experiments are now coming to their conclusion.

The Intrex system has consisted of an on-line, interactive catalog for nearly 20,000 documents in specific areas of materials science and engineering. In addition to this bibliographic information, full text of 15,000 of the documents has been available for a remote store of 1,500 sheets of microfiche. Terminals in the Barker Engineering Library, the Electronic Systems Laboratory, and the Center for Materials Science and Engineering have provided access to this store.

The past year's activities have included thorough study of the utility and effectiveness of the components of the Intrex system. Approximately 1,000 users have utilized the system during this period and provided enthusiastic support for the information transfer concepts developed during the past seven years.

The cost analysis for an operational information system with Intrex features indicates that large-scale systems can be financially self-sustaining after initial development costs. Clearly, however, such systems must be made available to large numbers of users via information networks. While Intrex has proven the technical feasibility of such systems, difficult administrative, economic, and political problems lie ahead.

While awaiting the resolution of these problems, information transfer scientists at M.I.T. will turn from Project Intrex to new tasks, initially in the area of network integration of disparate information systems.

CARL F. J. OVERHAGE

## Project MAC

Project MAC is an interdepartmental laboratory for computer research and development. The laboratory includes four separable but interacting Divisions, staffed by approximately 320 faculty members, staff members, and students. The four Divisions and their respective leaders are: Fundamental Studies, Jack B. Dennis; Systems Research, Jerome H. Saltzer and Fernando J. Corbato; Dynamic Modeling and Graphics, J.C.R. Licklider; and Automatic Programming, Fernando J. Corbato and William A. Martin. The academic members of Project MAC are members of the Departments of Electrical Engineering, Mathematics, and Architecture, and the Sloan School of Management. For the third consecutive year, Project MAC has deliberately fostered participation in research by undergraduates. The number of undergraduates at Project MAC during the last year averaged 74. The computer facilities at Project MAC presently include: 2 PDP-10's, one with graphic capability, and both with 260,000 words of core memory; 1 PDP-8 with graphic capability; an Evans and Sutherland display. In addition, MAC is a major user of the MULTICS system, a GE-645 with two central processors and 400,000 words of core memory. At MAC there are 77 remote computer terminals. Most terminals are typewriterlike, but 14 have display screens, and 6 have displays with their own small computers (IMLAC PDS-1).

Project MAC was started in 1963 with Advanced Research Project Agency (ARPA) support for research in computer science. The name MAC was derived from our early goal, Machine-Aided Cognition, and a tool for working toward that goal, Multiple-Access Computers. The major thrust of the early research at Project MAC was in pioneering work on time-sharing. Work on the Compatible Time-Sharing System (CTSS), which was already in progress at M.I.T., was undertaken and completed at MAC with a clear demonstration of the feasibility and convenience of time-sharing. CTSS was the first major time-sharing system to be built; it had an important impact on the community of computer users. In 1964 Project MAC began work on MULTICS in a serious effort to transform the computer system into a public utility, much as in the case of the telephone system.

MULTICS evolved and tested many pioneering ideas, such as: an integrated file system,

controlled access, segmentation, paging, virtual memory, and multiprocessing. Theoretical research and MULTICS implementation both proceeded simultaneously. By 1969 the work on the MULTICS system had advanced sufficiently to make MULTICS available to the entire M. I. T. community on a regular basis through M. I. T. 's Information Processing Center. MULTICS has since been in continuous operation and has seen substantial growth in both the number of users and in the size of the machine itself. The GE-645 computer which MULTICS is currently operating is soon to be replaced by new hardware specifically designed for MULTICS by Honeywell Incorporated.

In recent years the activity of Project MAC became more diverse and other areas of research gained in strength. The character of Project MAC changed from a single orientation to a laboratory conducting research on many aspects of computer science. In December, 1970, the Artificial Intelligence Group of MAC, which has itself grown substantially in size, separated from MAC and became the M. I. T. Artificial Intelligence Laboratory. During 1971, after intense discussion of what major research Project MAC should undertake, the laboratory emerged with a new research direction aimed towards Automatic Programming.

The purpose of Automatic Programming is to make computers more easily used by laymen. Examining the various fields in which computers are, or could profitably be used, attempts will be made to incorporate computer methods into a computer system so that communication with it could be made in the form of desires and goals, stated in a "natural" language, instead of the present method of specifying the solution to the problem in terms of an algorithm. In the case where they system did not have a good method for dealing with a problem, the user could introduce, test, and verify an algorithm which would be added to the system's repertoire of expertise. Communication difficulties with the computer would be eased because the computer system, with expert knowledge of the field under discussion, would exhibit common sense in its communications back to the user. MAC already has gained experience in dealing with the incorporation of knowledge into a computer from the pioneering work done with MATHLAB. MATHLAB has successfully demonstrated the advantages of systems with expert knowledge by its excellent performance of symbolic integration and other symbolic mathematics.

As in years past, Project MAC was supported in 1972 primarily by funding from the Information Processing Techniques Directorate of ARPA. Several projects at MAC were funded by other agencies, notably the Office of Naval Research (ONR) and the National Science Foundation (NSF).

Project MAC has received a substantial grant from NSF which largely supports the effort of MAC's Division of Fundamental Studies, which deals with basic computer science.

EDWARD FREDKIN

## Research Laboratory of Electronics

Established at the end of World War II as the Institute's first interdepartmental laboratory, the Research Laboratory of Electronics has evolved a research environment for faculty members and students. Initially organized to encourage interactions between teaching and research in the Departments of Electrical Engineering and Physics, the Laboratory has had projects involving participants from as many as a dozen departments. The research groups, currently numbering about 30, conduct research in three broad areas: general physics; plasma dynamics; and communication sciences and engineering.

All of the research in R. L. E. involves academic faculty members and students. Approximately 100 members of the faculty are affiliated with the Laboratory, working with about 300 graduate students and nearly 100 undergraduates. The research in R. L. E. spreads

over a broad spectrum of topics and thus provides opportunities for a wide variety of student thesis work. During the past year, the research provided the basis for 38 Doctoral, five Engineer's, 36 Master's and 37 Bachelor's theses.

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.

## General Physics

The research in general physics is largely based on atomic phenomena. The experimental techniques required to observe 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 the extensive use of computers. A few of the research topics in this area are mentioned below.

Professor John G. King and his associates in the molecular beams group report that during the past year the feasibility of the molecular microscope has been definitely established and they are now starting a number of experiments to establish its scientific utility. These experiments include a study of the binding of various small molecules to surfaces of biological interest such as lipid, carbohydrate and protein with a view to identifying similar regions on the surface of cells, the study of molecular emissions from nerves conducting impulses, and the transmission of vapor through tissue. The group is also exploring the application of the instrument in such widely different fields as astrophysics and material science in which the behavior of irregularly distributed fractional monolayers is of importance, and difficult to study by other methods.

Theoretical analysis and experimental studies support the suggestion made by Professor Malcolm W. P. Strandberg that second harmonic microwave spectroscopy can be a useful new tool for spectroscopic analysis.

The radio astronomy group, involving Professors Alan H. Barrett, Bernard F. Burke, Richard M. Price and David H. Staelin of the Departments of Physics and Electrical Engineering, are studying microwave spectral lines of both the interstellar medium and the terrestrial atmosphere. The study of interstellar molecules has led to very-long-baseline interferometric observations involving simultaneous use of radio telescopes in various countries. The results show that some spectral line sources are as small as 0.0003 arc-seconds in diameter. The atmospheric studies are concentrated on the microwave properties of molecular oxygen as observed both from the ground and from spacecraft. One by-product of this effort is a microwave temperature sounding experiment to be launched on the Nimbus E and F meteorological satellites.

Professor Rainer Weiss and Dr. Dirk Muelhner have measured the spectrum of the isotropic background radiation in the far-infrared. In balloon flights made in June and September 1971, they established that the spectrum obeys a black body distribution in the region from 1 to 12 $cm^{-1}$ consistent with a universe temperature of 2.7° K. The spectral region above 12 $cm^{-1}$ was found to be dominated by radiation from atmospheric ozone and water vapor.

The work of Professors Hermann A. Haus and Paul V. Hoff and their students led to an observation of "negative" saturation in a Transverse Excited Atmospheric Pressure (TEA) $CO_2$ laser; namely, the gain increases temporarily as radiation power is extracted from the lasing medium. The effect, which has been explained theoretically, is of importance in amplifying pulses of $CO_2$ radiation.

Professor Shaoul Ezekiel and his students have succeeded in using an $I_2$ absorption line observed in a molecular beam to stabilize the frequency of an argon laser. A long term stability of less than $3x10^{-11}$ has been achieved. The use of molecular beams promises a high degree of long-term stability and resettability of the laser frequency.

## Plasma Dynamics

A major goal of the plasma dynamics program is extension of the basic understanding of phenomena in ionized gasses and in solids in relation to such problems as controlled fusion, space physics and collective phenomena in solids. The research includes methods of producing highly ionized plasmas by electron beam injection, high power lasers, microwaves, low pressure arcs and so forth. Plasma diagnostic techniques involved measurements in various portions of the electromagnetic spectrum (microwave, millimeter wave, infrared, optical).

Professors William P. Allis, Sanborn C. Brown, Bruno Coppi and E. Victor George of the plasma physics group have been engaged in four major areas of study. 1) Experimental and theoretical work concerning the physics of high temperature plasmas carrying high currents, typically of the order of $10^3$ A/cm$^2$. The Alcator Toroidal device, built in collaboration with the Magnet Laboratory and the Departments of Electrical Engineering and Nuclear Engineering, is nearing completion. In addition to Ohmic heating, injection of microwaves is being contemplated with the view of enhancing the plasma temperature and its d. c. resistivity. 2) The behavior of low frequency instabilities in a fully ionized plasma confined by a two-dimensional magnetic field is being studied using the SLIM linear quadrupole facility. Studies of these phenomena are of interest for the understanding of both astrophysical plasma phenomena and the operation of controlled fusion plasma systems. 3) Through the courtesy of EG&G we have obtained, on a long-term loan, a relativistic beam machine which is now producing a 100 KA beam of electrons with an energy of 250KeV. The major aim of this work is to inject the beam into a high density plasma and initiate turbulent heating of the medium. Such turbulent heating appears to have considerable promise in raising temperatures of plasmas to a range of interest to fusion. 4) The production and heating of plasmas by means of high intensity lasers is being carried out in our laborarory. Work is under way to study the interaction of intense $CO_2$ laser beams with target plasmas. In conjunction with this work a strong diagnostics effort using novel spectroscopic techniques is being pursued.

## Communication Sciences and Engineering

This research spans a broad range of topics pertinent to communication processes in man-made and living systems as well as interactions between them. Fundamental studies of signals and systems are coupled with various applications such as speech and picture transmission, seismic detection and optical communication channels. A major portion of the effort is related to the life sciences. A combined program of research and training in communications bio-engineering includes areas such as communications biophysics, neurophysiology, cognitive information processing and speech communication. Much of this work concerns the sensory or perceptual mechanisms and the related program in linguistics seeks to improve our understanding of languages, which form the basis for communication.

During the past year, Professor Arthur B. Baggeroer participated in the NSF International Decade of Ocean Exploration with personnel from the Woods Hole Oceanographic Institution. This work involved the detection and estimation of marine seismic structures aboard the R/V Atlantis II. Professor Baggeroer plans to continue work in this area.

The cognitive information processing group, under the direction of Professor Murray Eden, is studying the ways in which humans process visual and auditory information, as well as computational techniques to simulate these cognitive activities. Professor Barry A. Blesser and Dr. David Ozonoff have completed the first phase of their study of perceptual

error made by radiologists reading chest x-ray films, and found that 8 percent of the errors made would significantly affect the patient's management, while 27 percent of the errors were clinically significant but would have no effect on the patient's management.

Professor Ian T. Young has continued his work on cell contact adhesiveness, as well as the study of the distribution of hemoglobin in red blood cells. Similarly, Dr. Gosta Granlund, by means of characterizations of chromosomes in terms of a set of Gaussian distributions, has been able to classify chromosomes with an accuracy of 96 percent, making it possible to distinguish between specific individuals on the basis of chromosome data from different cells.

Professor William F. Schreiber has successfully demonstrated a new digital facsimile transmission system using equipment based on laser scanning techniques, and is starting to work on an x-ray transmission system using the same principles.

Professor Donald E. Troxel has continued his work in computer-aided logical design with the development of an interactive program for on-line construction of logic diagrams in terms of previously defined logical elements and subsystems. Professor Francis F. Lee has extended his static tactile pitch feedback for deaf speakers to a dynamic system which allows deaf speakers to exercise some degree of control over their speech intonation and rhythm.

In the area of text-to-speech conversion, Professor Jonathan Allen has demonstrated a system which is capable of converting the text representation of any English word to speech by utilizing an extensive dictionary, letter-to-sound rules, and algorithms for computing stress and low-level coarticulation effects. This system serves as a partial model for reading aloud, and is of direct use to teachers of reading as well as in sensory aids for the blind.

Research in speech communication, under the direction of Professor Kenneth N. Stevens, Professor William L. Henke, Professor Alan V. Oppenheim, and Dr. Dennis H. Klatt, has included several projects relating to the processing of speech by humans and by machines. Work on speech synthesis by computer, which is motivated in part by the need to provide a speech output from the reading machine of the cognitive information processing group, has progressed to the point where highly intelligible speech is being generated, partly as a result of improved rules for the timing of synthesized utterances. Novel methods of digital signal processing, implemented in cooperation with Lincoln Laboratory, are being applied to the extraction of parameters from the speech signal, and these parameters are being used as imputs for experimental schemes for recognition of speech sounds and for speaker identification. Research on fundamental aspects of speech production and perception is continuing, with new emphasis on the temporal aspects of speech and on the application of studies of neuro-physiological control of movement to the formulation of theories of speech production. Research that seeks a biological basis for the classificatory systems and structures used in language includes studies of the classification of early vocalization of infants and experiments that examine the order of acquisition of the perception and production of various segmental features.

The communications biophysics group, under the direction of Professor William M. Siebert, has continued its efforts, in cooperation with several hospitals, to apply the devices and methods of modern technology in ways that will enhance our understanding of various biological systems. Emphasis remains divided, as in the past, between basic science studies (e. g., studies of the physiological and psychological properties of the auditory system) and applied studies (e. g., efforts to apply engineering technology to practical problems in patient care, health delivery systems, and clinical research). The proportion of effort, however, going into applied studies continues to grow.

Work in auditory psychophysics, supervised by Nathaniel I. Durlach and Professors Louis D. Braida, H. Steven Colburn, and Julius L. Goldstein, has included continued study of combination tones, periodicity pitch, binaural phenomena, intensity resolution and short-term auditory memory, and continued development of computer-controlled laboratory facilities. A particularly significant accomplishment may be the discovery (in collaboration with a visitor to our laboratory, Professor F. A. Bilsen) of a new pitch phenomenon, "dichotic repetition pitch," which provides important information on those auditory mechanisms that indicate pitch perception. Studies related to the development of improved hearing aids and new methods for the diagnosis of hearing impairments have been expanded. For example, one interesting investigation combines a new psychophysical technique based on aural combination tones with acoustic impedance measurements as a function of external pressure to study middle ear mechanisms and the acoustic reflex. Other studies concerned with the effects of various kinds of speech transformations of potential prosthetic interest are in progress.

The Eaton Peabody Laboratory of Auditory Physiology continues as a joint operation of M.I.T. and the Massachusetts Eye and Ear Infirmary. Recent experimental studies of the auditory system, under the supervision of Dr. Nelson Y.S. Kiang and Professors William T. Peake, Thomas F. Weiss, and John J. Guinan, Jr., have included measurements of sound pressure in the fluid of the inner ear of cats, and a survey of responses of single cells in the cochlear nucleus which has led to the association of classes of responses to sound with classes of nerve cells based on cell morphology.

Biomedical engineering research has continued its expansion under the supervision of Professors Stephen K. Burns and Roger G. Mark. Although the development of bioinstrumentation remains an important objective, our interest extends to a variety of practical problems in patient care, health delivery systems, and clinical research. Many of these studies are carried out in cooperation with the Boston City Hospital. Among recent developments are a variety of devices for detecting, transmitting, recording, processing, and displaying clinical variables such as EKG, blood pressure, etc.

Other achievements of members of the communications biophysics group include studies of the functioning of the lateral line organ in amphibians, Professor Lawrence S. Frishkopf; studies of the electrical properties of nerve membrane, Professor Thomas F. Weiss; a new analytical model of the cochlea, Professor William M. Siebert; and studies of the neuroelectric correlates of behavior, Dr. Robert D. Hall.

During the past year the main objective of the linguistics group has continued to be to discover something about the mental capacities of man by investigating language in its different manifestations.

Studies in the areas of syntax and semantics occupy probably more time of more individuals than any other areas. In surveying the work in this area it is necessary to remark that in spite of the publicity currently being given to the controversy between "generative semanticists" and "interpretivists," the controversy has only had very slight effect on the work being done here.

In a recent study by Professor Noam Chomsky on "Conditions of Transformations," he proposes a number of formal constraints which limit the power of various devices used in syntax and semantics and attempts to show that the same limitations hold in both domains. If Chomsky's suggestions are borne out by further research they will, at the very least, have made explicit a particular aspect in which semantics and syntax are identical. They will thus have served to clarify one of the classical controversies in the study of language, namely the relationship between syntax and semantics.

In the work of Professor John R. Ross, the inseparability of the two fields, syntax and semantics, is taken for granted and much effort is devoted in trying to deal with examples that appear to be unclear or to counteract the claim. Thus, in his important paper, "Act," Professor Ross analyzes verbs of action with the aim of showing that sentences containing such verbs are "always embedded in the object complement of a two-place predicate whose subject is identical to the subject of the action verb and whose phonological realization in English is do."

Work on the theory of phonology has also been carried out by Professor Paul Kiparsky who has been especially interested in the question of rule interaction. His main achievement during this year, however, has been an extensive paper on the Indo-European accent, solving some of the classical problems in this venerable field of study.

Studies on more traditional areas of phonology occupied much of the time of Professor Morris Halle. His efforts have been directed, on the one hand, toward the further improvement of the universal framework of phonetic features and, on the other hand, toward gaining a better understanding of the part of the grammar that is responsible for work formation.

Much of the time of Professor G. Hubert Matthews as well as that of Professor Kenneth L. Hale was occupied by work in support of efforts to institute and expand literacy in the native langugage of the indigenous population of North America (primarily Indian and Eskimo). This work involves all aspects of linguistics, from detailed phonetics to semantic theory, and has resulted in publications in these areas by Professors Hale and Matthews.

Psycholinguistic research is being carried out primarily under the guidance of Professors Jerry A. Fodor and Merrill F. Garrett of the Department of Psychology. Dissertations by D. Caplan and S. Fischer dealing with topics in psycholinguistics were completed during the year. Professors Fodor, Garrett and T. G. Bever of Columbia University are at present completing the manuscript of a major book dealing with the entire area of psycholinguistics.

In the neurophysiology group, supervised by Professor Jerome Y. Lettvin, Eric Newman has done a high-speed cinematic analysis of Stentor coerulus with particular interest in two topics: 1) the mechanism of contraction, and 2) evidence of coupling between two jointed Stentor. Richard Greenblatt has been working on the optic lobe of octopus where he is recording the behavior of various ganglion cells immediately under the first plexiform layer. Mark Lurie has recorded long slow d. c. components of the electroretinogram in the frog. This component, commonly called the C wave, requires for its production the presence of the subjacent pigment epithelium of the retina.

Susan Udin, with the assistance of Claire Moore, has been doing an extensive study of the properties of remapping from the optic nerve to tectum after severance of the optic nerve in adult frogs. The maps formed by the fibers of different functions seen to reconstitute themsleves at profoundly different rates, and the receptive field characteristics themselves may perhaps be abnormal at early stages of regeneration. Robert Stephenson has been studying the relationship between muscle activity in normal and grafted supernumerary limbs in salamanders. Edward Gruberg, while working on whether or not neuronogenesis occurs in the tectum after optic nerve section, has found a critical period after such section where strong cytogenesis occurs in the more caudal aspects of the tectal ependyma.

Dr. Stephen Raymond has been involved in two projects. The first entails simulation of conduction of nerve impulses in the branched teledendron. The second project is an attempt to analyse the basis for the long-term threshold changes that follow impulses. Such threshold changes occurring in a partially blocked fiber are sufficient to account for the intermittent conduction that he has shown to be a characteristic of such partially blocked axons.

Dr. Lettvin has developed a complete membrane model in which it is possible to show the nature of an ionic conductance in terms of a 4-diode bridge together with proofs that such a model is necessary and a minimum. Stripped down versions of this model, consisting of a 6-transistor circuit, are now being used in teaching laboratories in several other institutions.

HENRY J. ZIMMERMANN

## R.O.T.C. Programs

As described in the accompanying reports from each of the commandants, the three R. O. T. C. units at M. I. T. continue to function effectively. The new curricula have gone into operation with relatively minor dislocations, as was anticipated in view of their evolutionary nature. Enrollment in the programs holds steady, neither increasing nor decreasing drastically; the spirit of the students appears positive, though not uncritically so. Community criticism of the R. O. T. C. presence here has diminished in level and extent but it has not disappeared; the forceful occupation of the R. O. T. C. offices in May provided proof of that. This and other significant points of the year's activity will covered in the following, with no inference of relative importance to be drawn from their order.

The committee sent a letter to each R. O. T. C. enrollee offering assistance or counsel if desired, identifying its membership, mentioning the availability of legal advice and inviting any student with suggestions to put them forth. Among the latter, not surprisingly, was one advancing the idea of student membership in our committee. After some discussion, we concluded that we would prefer to invite students to attend some of our meetings next year before making any further commitment on this point.

Some subject availability and scheduling problems were encountered in the new Air Force curriculum in the writing/self-expression area. Consultation with Professor Douglas and his colleagues led to planned remedial actions which will go into effect in academic year 1972-73. It is expected that these will be effective. We have received some informal expressions of concern from the Air Force regarding academic or degree credit for certain components in their curriculum. Since this is neither a simple, short-term matter, nor limited exclusively to the Air Force, we plan to explore it carefully and fully, on a more or less continuous basis by means of a standing subcommittee appointed for the purpose.

For the first time in its existence here, the Navy R. O. T. C. unit has received authorization to enroll as many as 25 undergraduate scholarship students per year. This comprises a valuable additional element to the unit and one toward which much patient effort was expended by Captain Porter and some of his predecessors. The committee welcomes this opportunity to again commend them for their achievement.

On May 12-13, 1972, for a period approaching 24 hours, the R. O. T. C. Offices in Building 20 were forcefully occupied by a group of 50-75 people, some of whom were affiliated with the Institute. Many of our committee were present as observers at various times during the incident. All military personnel who were involved conducted themselves with wise restraint, which was one important factor in limiting the impact of the event.

Three personnel actions merit mention: 1) The former A. F. R. O. T. C. unit commander, Col. George P. Gamache, died in a B-52 crash in Florida, in the spring of 1972. Those of use who knew Col. Gamache respected him as an officer and liked him as an individual; we sorrow for his death. Chairman Howard W. Johnson spoke for the entire Institue community when he conveyed sympathy to Mrs. Gamache and their children. 2) Col. Marshall O. Becker, Army R. O. T. C. commandant, reached retirement age in early 1972, and was succeeded by Col. J. Elliott. Col. Becker shared many stressful days with our predecessor committee several years ago, always with equanimity, tact and quiet good humor which in no way lessened his professional dedication. All of us share the hope that his retirement will be a

pleasant and rewarding experience. 3) David Yohn of the Dean's staff also leaves M.I.T. this summer. Though only briefly associated with our committee, his effectiveness in student counseling will be missed after his departure.

## Army R.O.T.C. Activities

Enrollment in M.I.T.'s Army R.O.T.C. Program at the end of 1971-72 stood at 61, down 11 from 1970-71. Of that new enrollment total, 22 were new freshmen and one entered the program from Basic Summer Camp into the third year through the Two-Year Program. Twenty-one of these cadets attended M.I.T. with R.O.T.C.-provided scholarships with a total annual value of approximately $63,852.38. Seventeen of the scholarships were for four years, three for three years, and one for two and one-half years.

Academically the past year saw continued implementation of the Recommendations of Curricula promulgated by the M.I.T. R.O.T.C. Study Committee in its report of April 1, 1970. The changes in curriculum have proceeded smoothly.

Output of commissioned officers for the current year is projected at 20. Efforts to match these individuals with their personal interests and desires in respect to branch assignments within the Army have continued to be successful. Present projection of branches in which these individuals will serve is as follows: Infantry -- 2; Signal Corps -- 4; Ordnance Corps -- 7; Medical Services Corps -- 2; Chemical Corps -- 2; Adjutant Generals Corps -- 1; Corps of Engineers; and Quartermaster Corps -- 1.

Eleven of the above have been designated Distinguished Military Students. Three have applied for and two have been offered Regular Army commissions.

The most significant event in the area of extracurricular activities was the reestablishment of a local chapter in the National Society of Pershing Rifles, a military honor society for R.O.T.C. Cadets. Dormant since 1967, the local chapter was formally reactivated in May entirely on the initiative of the cadet membership. The Rifle Team fired in a total of four postal matches during the course of the year, while the Commando Group experienced one of its most active years ever, including seven field trips to either Fort Devens or Camp Edwards, Massachusetts. In mid-November, two M.I.T. cadets were guests of the U.S. Military Academy at West Point for three days. Some 15 others spent three days during Independent Activities Period at Fort Belvoir, Virginia, receiving orientations on the Army Engineer School, Combat Developments Command, Computer Systems Command, and Night Vision Laboratories. In April, another group of cadets toured the Army Materiels and Mechanics Research Center, at Watertown, Massachusetts.

## Navy R.O.T.C. Activities

The current enrollment in the N.R.O.T.C. Program is 28 midshipmen. The distribution by Naval Science Year Group is as follows: Freshmen -- 12; Sophomores -- 7; Juniors -- 5; and Seniors -- 4.

The Bureau of Naval Personnel has approved our request that this unit participate in the N.R.O.T.C. Scholarship Program. Two midshipmen were transferred to scholarship status and three admitted freshmen have been confirmed by the Navy for the 1972-73 academic year. It is anticipated that a substantially larger number of scholarship students will be enrolled for the 1973-74 academic year as the opportunity is publicized.

The Delayed Active Duty Program designed for graduate study after commissioning continues with one graduating midshipman currently admitted to graduate study in the Department of Ocean Engineering. This newly commissioned officer joins the three officers continuing in graduate school. Three other officers who entered the Program in 1970 have received their graduate degrees and will report for active duty this summer. Two are going to research-

oriented assignments ashore.

The Naval Science curriculum continues to be well received by the midshipmen and by civilian students taking these subjects. Student evaluation questionnaires praise Seminar 136, The Art and Science of Navigation, sponsored by the Department of Ocean Engineering with the assistance of Lieutenant Welch of the staff. This seminar attracted 14 students, including four midshipmen, for the study of coastal piloting techniques and basic celestial navigation. The highlight of the seminar was their manning a Navigation Training Craft provided by the Naval Officer Candidate School at Newport, Rhode Island. This seminar served as an ideal model of midshipmen and non-R.O.T.C. students working together with a common objective. The midshipmen learned to appreciate the value of thorough planning and organization to accomplish the cruise evolution while all the students put theory into practice as they were given the responsibility for safely navigating their craft for an entire day in Narragansett Bay. The seminar was enchanced by visiting authorities on such topics as maritime law and meteorology.

A successful Navy-Air Force seminar in National Security Affairs was conducted this year. Visiting Lecturers from M.I.T., Tufts and the Services gave the students an appreciation of the role of the uniformed services in world politics.

A pilot seminar on Ship Applications of Control System Theory shows promise of developing into a popular subject. Visiting Professors from five M.I.T. departments lectured on various topics relating to the principles applied in Naval Ship Systems. The Department of Aeronautics and Astronautics provided a graduate student to assist in combining components into a functional control system.

In conjunction with the R.O.T.C. curriculum, several tours were conducted to Navy facilities. The tours included one weekend trip to the Naval War College, the Naval Destroyer School, and the Submarine Base at New London. Several midshipmen spent a weekend at sea aboard a destroyer based in Boston. Near the end of the academic year, a nearly completed ship was toured at the shipyard in Quincy. This tour group included students of subject 13.64J, Hydrospace Vehicles, sponsored by the Department of Ocean Engineering.

This summer, three junior midshipment will participate in an industrial Engineering Cruise as an alternative to the traditional six-week cruise at sea. Since this unit is uniquely oriented to produce engineering duty officers, a more meaningful summer cruise was proposed and approved. The midshipmen will be assigned to the Material Staff of Commander Cruiser Destroyer Force, Atlantic Fleet. They will inspect ships of the fleet, participate in solving fleet maintenance management problems aboard a fleet repair ship and a destroyer tender, and attend a Machinery Maintenance Course at the Naval Destroyer School, Newport, Rhode Island.

Extracurricular activities receive continued support as they are integrated with formal academic and unit subjects. In February, approximately 160 midshipmen, officers, and Navy friends gathered in a formal Mess Night. The traditional formal dinner was at the Boston Naval Shipyard Officers Club. In May, the annual Tri-Service Awards Banquet was held at the Faculty Club. Two midshipmen were distinguished as the recipients of the Society of American Military Engineers award. Only 30 such awards are given nationally. All of the Midshipmen Pistol Team received individual honors in the First Naval District competition.

Particulary noteworthy are the accomplishments of Midshipman Barber (M.I.T. Class of 1973, Course XVI). He was elected Commanding Officer to the Tri-Service Commando Group. He is the first M.I.T. midshipman to be selected to go in a nuclear submarine on

a two-month POLARIS cruise, and he is the first midshipman enrolled in the N. R. O. T. C. Scholarship Program.

In September, 1971, Lieutenant Donald Peter Welch relieved Lieutenant Commander John Hudson Beaton as Engineering Instructor. Lieutenant Welch received his degree in chemical engineering from the University of Massachusetts. Lieutenant Commander John D. Fedor will depart in July to attend the Naval War College. His relief will be Lieutenant Mark Ryan, a graduate of Harvard University. Lieutenant Robert J. Leonard has reported administratively to complete his master's degree requirements and prepare for his staff appointment.

## Air Force R.O.T.C. Activities

The Air Force R. O. T. C. program began the year with 59 cadets, broken down in this manner:

| | Undergraduates | Graduates |
|---|---|---|
| General Military Course | | |
| AS 100 (Freshmen) | 26 | 0 |
| AS 200 (Sophomores) | 8 | 0 |
| Professional Officer Course | | |
| AS 300 (Juniors) | 7 | 3 |
| AS 400 (Seniors) | 8 | 7 |
| | 49 | 10 |

Freshman turbulence was high and several very promising cadets decided that an officer's commission was, after all, not what they were seeking. This attitude was especially noticeable following the draft lottery in February. For the first time, however, we had authority to enroll freshmen in our program at the beginning of the spring term. The number of new freshmen who joined at that time nearly offset earlier losses, and we ended the year with 23 AS 100 cadets. This is by far the largest freshman enrollment in recent years and augurs well for the future. Also, for the first time we enrolled three female cadets, all in the AS 100 group.

Two AS 200 scholarship cadets were discontinued for contract violations. Neither is to be involuntarily called to active duty as an enlisted man.

The scholarship program continues to grow. A total of 25 undergraduates, comprising 46 percent of our enrollment, are supported by Air Force scholarships that pay full tuition, the mandatory health fee, a book allowance, and $100 per month for subsistence. As the result of increased emphasis on Air Force R. O. T. C. as a major source of pilots and navigators, scholarships are presently being awarded only to cadets who are qualified for, and wish to enter, flying training. Because of this, Detachment 365 received only five new scholarships this year, all for pilot or navigator candidates. Qualified cadets from the support skills area are being carried on an alternate roster by Headquarters A. F. R. O. T. C. and will be considered for scholarships if the criteria are changed.

In order to alleviate the current over-production of support skills officers, each Air Force R. O. T. C. detachment has been given a quota limiting the number of such male cadets that

can be entered into the Professional Officer Course portion of the program. This quota for the M.I.T. Class of 1974, this year's AS 200 cadets, the first group to which it applies, is seven. It did not prove to be limiting factor with this group since nearly all are pilot or navigator candidates. In future years, however, it may well mean that some qualifed Category II (scientific and technical support skills) cadets will be unable to enroll in the POC.

A year's experience with the Alternate Curriculum Program, which substitutes regularly accredited M.I.T. subjects for three terms of the A.F.R.O.T.C. course, revealed two major problem areas: an adequate number of approved alternate subjects, and insufficient contact between cadets and their military instructors. The first difficulty was relatively easy to resolve. A revised Memorandum of Agreement between the Air Force and M.I.T. which provided for expansion of the list of alternate subjects from 8 to 17, was negotiated in May. While the effects of decreased cadet contact can be minimized, there is no way of eliminating the problem while still retaining the Alternate Curriculum Program. This approach is well received by the cadets since it permits them to simultaneously fulfill Institute humanities and Air Force R.O.T.C. requirements while accruing course credit. Lessened classroom contact, however, reduces our ability to guide, shape and evaluate the cadets. Thus, from the Air Force viewpoint, the program must be accorded mixed marks.

The experimental approach to Corps Training, the A.F.R.O.T.C. biweekly laboratory period, instituted last year, was continued and expanded. Our objectives were three-fold: 1) to stimulate cadet interest in both the Air Force and the R.O.T.C. program; 2) to increase total cadet involvement; and 3) to meet course goals in a way that the cadets would find meaningful. To these ends we continued the innovative "New Directions in Corps Training" program of student presentations, relating their academic disciplines to ongoing Air Force projects. This was supplemented with a series of "Training Weekends," one each term, at a nearby Air Force base. Designed to overcome the difficulties of conducting required drill and ceremonies instruction on campus, these extended training periods proved to have several additional, and unforeseen, benefits. Most notable was the rapid integration of new cadets into the Cadet Corps and the concurrent development of an esprit de corps, a sense of "belonging" to the unit. The weekends also provided an excellent opportunity for them to examine the Air Force and the role of the Air Force officer in depth. A cadet survey indicates that these approaches to Corps Training were highly successful in their eyes as well as ours.

Field trips were taken to Andrews Air Force Base, Maryland, Wright-Patterson Air Force Base, Ohio, and Randolph Air Force Base, Texas, in addition to base tours conducted as part of the training weekends at Pease Air Force Base, New Hampshire, and L.G. Hanscom Field. Although student interest was high, heavy academic demands and extracurricular activities limited participation on most field trips to approximately 20-25 percent of the Cadet Corps.

The Lt. Col. Jay Zeamer Squadron of the Arnold Air Society, and A.F.R.O.T.C. extra-curricular activity at M.I.T., was extremely active in community and campus projects during the year. Most notable in the latter category was their role as co-sponsor of the semi-annual M.I.T. blood drives, held in November and March. At the National Conclave of the Arnold Air Society, held in Dallas during late March, the Squadron presented a study on recruiting, retention and apathy toward R.O.T.C. on the nation's campuses. Finally, in recognition of the 25th anniversary of the United States Air Force, the Squadron published a special issue of their newspaper, Countdown.

## Sea Grant Program

The M.I.T. Sea Grant Program's initial Coherent Area Project of June, 1970, was reviewed and approved for renewal and FY 72 support by the National Sea Grant Office through the

issue of Grant Number 2-35150 for $315,000 effective July 1, 1971. We have received three supplemental grants from the National Sea Grant Office for added project efforts that increase the grant total to $392,000. M.I.T. matching funds of $289,150 which include the second installment ($100,000) of the three-year grant by the Henry L. and Grace Doherty Charitable Foundation Inc., give us a total program effort of $681,150. This is a doubling of our Program effort in our second year. The success of M.I.T.'s two-year Coherent Area Program will be recognized by the National Sea Grant Office through the designation of M.I.T. as a Sea Grant Institution and the award of an Institutional Grant for FY 73.

A brief description of our program development plans will place our 1971-72 accomplishments in context. During the first year, 1970-71, we concentrated on establishing the program within M.I.T., organizing the management, and developing faculty interest and participation. In this second year, we have worked to broaden the M.I.T. participation base, to develop strong industry and state agency interest and support, and to initiate the advisory services and liaison efforts required for a successful institutional program.

For the third year, beginning July, 1972, we see at least four primary objectives: 1) to develop further state-industry participation and support; 2) to develop advisory services and marine liaison operations into a strong, effective program element; 3) to strengthen further and to orient more clearly our long-term research plans through our liaison services feedback and our Advisory Councils; and 4) to strengthen the coordination, cooperation, and participation of other academic institutions in the growing M.I.T. Sea Grant Program.

Basic to, and growing out of, the specific accomplishments of the FY 71 and FY 72 program efforts have come three basic themes which orient and direct the M.I.T. Sea Grant Program. They also provide the necessary cohesiveness for both short- and long-term projects. These themes are: the Massachusetts Bay Focus; the New England Focus; and Ocean Utilization. We have selected area themes, rather than the usual topical categories, to take advantage of the multi-disciplinary and interdisciplinary systems approach to problem solving. Topical categories can, do, and will run through and interconnect the three theme areas so that problems in one area will benefit from research in the others. Thus, specific research efforts may serve different problems in two or three areas simultaneously.

In keeping with the National Sea Grant goals, we want our program to have the greatest benefit to the widest possible audience. Since it is not feasible to work on all possible research in all areas or on all topics simultaneously, we believe the area theme approach permits selection of those projects that will have the broadest interest and greatest potential benefit from the many proposed, thereby helping the selection, by priority, of the most important ones. The Sea Grant Program can also be flexible and adaptable to include emerging new projects which evolving needs identify.

Specific highlight accomplishments which reflect the breadth and vigor of the FY 72 Program include the following. Eighteen technical reports have been or will be published. The book, Power, Pollution and Public Policy, a student research report under Professor Seifert's project, interdisciplinary systems design subject, has been widely acclaimed and Dr. Abel, National Sea Grant Director, considers it one of the best Sea Grant publication efforts to date.

In November a State-Industry Workshop was held to acquaint the leaders and decision-makers of our regions with the M.I.T. Sea Grant Program. As a result, a high-level State-Industry Advisory Council has been established. This group has already provided important insight and perspectives on current marine related problems, and it is also expected to provide a tie for increased state-industry participation and support.

Initial liaison efforts with the state have taken several paths. Provision of ad hoc advisory services to three state agencies and commissions has been made. Dean A. Horn, the Sea Grant Program Executive Officer, was appointed by Governor Sargent to the Special Legislative Commission on Marine Resources and Boundaries for the Commonwealth. Dr. Keil is a member of both the Massachusetts Commission on Ocean Management and a Task Force for the Secretary of Environmental Affairs. This Task Force is helping other Task Forces develop the perspectives and policies Massachusetts needs to develop its marine resources.

In response to public need, we proposed and received support for a supplemental project to study the environmental and economic impact of the potential offshore petroleum resource at Georges Bank. This study proposal is supported jointly by the New England Regional Commission, the New England River Basins Commission, and Sea Grant. The study's results will provide important criteria and methodology for the ultimate decisions on whether to exploit this resource.

Symposia were held on technology developments in "Working in the Ocean" and in "Ocean Transportation." These meetings, used to disseminate some of our project research results before final publication, were widely attended and well received. They were so successful that others will be held in 1972-73. In February, a special workshop was held with the National Marine Fisheries Service to identify needs for and applications of technology to improve utilization and conservation of our vital fishery resources. Several new project areas are being considered as a result.

The Student Summer Laboratory has proved to be a most effective new teaching program. Student enthusiasm and evaluations were unanimously high. The program for next year was selected by the ESSO Educational Foundation to receive one of their four nationwide academic support grants for FY 73.

The Massachusetts Bay Study, a major study to understand better the water environment of the entire Bay, was initiated this year. Research efforts have already developed several special computer-compatible instruments and have indentified specific problem areas where investigations can also be concentrated to yield concurrent specific results. During the next year specific projects will include studying sewage outfalls, termal plumes of power plant discharges, and environmental effects of a major dredging experiment that seeks to develop offshore sand and gravel resources without damaging the ecology.

Five research projects will be completed and their reports published this year. These are "Estuary Modeling," Professor A. T. Ippen; "Ocean Transportation," Professor E. G. Frankel; "Future of Atlantic Ports," Professor E. G. Frankel; "Costal Zone and Offshore Resource Management," Professor Devanney; and "Evolution of Marine Resources," Professor A. H. Keil and Instructor J. B. Lassiter III. The results of these efforts will be important additions to their fields and the information will be widely disseminated through the Sea Grant distribution.

Three research projects will be continued and completed as planned during FY 73. These are "Squid Food Products," Professor S. A. Goldblith; "Oceanborne Commerce and the Interoceanic Canal," Professor N. J. Padelford; and "Underwater Welding," Professor K. Masubuchi.

The success and rapid growth of the M. I. T. Sea Grant Program has been the result of support and commitment of the M. I. T. administration, the active interest and participation by a broad segment of the M. I. T. faculty and student body, and the developing interest and participation from the governmental and industrial sectors of the Commonwealth and New England. The designation of M. I. T. as a Sea Grant Institution is a significant milestone;

it means that we can anticipate continued annual support from the National Sea Grant Office by continuing to maintain a viable productive Program with the necessary matching fund support. The M.I.T. Sea Grant Program is dedicated to this objective and to the ultimate designation of M.I.T. as a Sea Grant College.

DEAN A. HORN

## Spectroscopy Laboratory

The research accomplishments of members of the research staff of the Spectroscopy Laboratory in the past year are related below.

The project on the ruling of diffraction gratings which Professor George R. Harrison has carried on for the past 25 years, its major objectives having been achieved, is now being brought to a conclusion. After a new method of controlling delicate machinery by means of laser light had been developed, more than 300 gratings, larger and of better quality than had previously been available, were produced on three ruling engines of progressively larger size. Some of these gratings showed a tenfold increase in light gathering and dispersive power, and many have been replicated by optical firms and are now in use in scientific laboratories throughout the world. Several of the largest are in use at astronomical observatories, where they were needed to utilize the full power of large telescopes. Two of the unique ruling engines constructed have been transferred to commercial optical firms, and the third, capable of ruling giant gratings weighing up to 200 pounds, will probably be moved to a new government laboratory at Kitt Peak National Observatory.

Professors Jeffrey Steinfeld and Stephen Kukolich and their research groups have observed a free-induction decay of the microwave absorption spectrum of ammonia following a rapid perturbation of the external conditions. This decay, which manifests itself as an exponentially damped transient nutation, is the Fourier transform of the absorption line. It is described by the same Block phenomenological equations which apply to pulsed Fourier-transform NMR spectroscopy. This effect can be produced by either of two equivalent procedures: causing a sudden change in population of the ammonia inversion levels with a pulse from a $N_2O$ infrared laser, or a sudden change in the molecular resonance condition itself by switching an applied electric field on and off. Analysis of the decay patterns will permit measurement of relaxation parameters for the system. With these procedures, many of the highly sensitive techniques developed for NMR spectroscopy can now be applied to microwave and optical systems.

In the Laboratory for Fundamental and Applied Laser Physics, Professor Ali Javan and his associates have made several important new contributions to ultra-high-resolution spectroscopy by means of tunable lasers. A new type of monochromatic source, potentially tunable throughout the infrared, has been constructed by A. Sanchez and S. Singh and Professor Javan. This development utilizes metal-oxide-metal diodes which have been perfected in our laboratories over the past few years. Previously, these diodes have been used as mixers and detectors of infrared radiation in the wavelength range 5-300 micrometers. In the present experiments, the sidebands, produced by mixing infrared radiation of a 10-micrometer carbon dioxide laser and microwave radiation of a klystron in the diode, are re-radiated. The radiation produced can be tuned by varying the klystron frequency. This source will be utilized in high-resolution spectroscopic studies.

A new type of laser amplifier, which has the property of amplifying waves of a given frequency propagating in one direction but attenuating waves of the same frequency propagating in the opposite direction, has been developed by N. Skribanowitz, I. Herman and Professors M. Feld and Javan. This device may be useful in the field of laser communications and in applications where complete decoupling of output signal and input signal is necessary. The idea makes use of the inherent anisotrophy in gain produced by optically pumping the Doppler-broadened

gas with an intense monochromatic source. The experiments were done on a sample cell of HF gas at low pressures ( 100 mTorr), pumped by the 3-micrometer lines of an HF laser. The uni-directionality was established by placing the amplifier cell in a ring cavity and noting that laser oscillation occurred preferentially in one direction. Uni-directional gain, both in the far-infrared (30-250 micrometers) and near-infrared (2.6 micrometers) has been achieved.

Professor Richard C. Lord and his associates have continued their studies of molecular potential-energy surfaces by high-resolution spectroscopy in the far infrared. With the help of their general theoretical treatment of pseudorotation in ring molecules, potential surfaces have been mapped for a number of rings having five or six atoms. One of these, the dioxene molecule, showed a highly complex far infrared spectrum that was deciphered with the help of the theory to yield an unusual potential surface. Its details suggested experiments in NMR spectroscopy that have now shown for the first time an inversion barrier to pseudorotation that is the same when measured by the two greatly different techniques of far IR and NMR spectroscopy.

Professor Lord's group has also extended their investigations of protein conformation by laser-Raman spectroscopy to show that different methods of denaturation of the enzyme lysozyme in aqueous solution lead to different conformations. They have concluded that reversible denaturation by thermal means leaves the backbone of the protein intact and affects only the side chains. Denaturation by strong lithium bromide salt solution, on the other hand, greatly disorders the peptide backbone, as does denaturation by the detergent sodium dodecyl sulfate. Chemical disruption of the disulfied cross links also leads to a disordered conformation, as expected. These results make it clear that laser-Raman spectroscopy will be a valuable technique for the biophysicist.

The following research workers took part in the research activities of the Spectroscopy Laboratory during 1971-72: Dr. T. B. Malloy, Jr., Mississippi State University, and Dr. Toyotoshi Ueda, Tokyo University.

RICHARD C. LORD

## Summer Session

In most respects, the 1971 Summer Session was similar to that of 1970. Registration of students in regular academic subjects remained essentially the same as in 1970; the relatively low attendance at Special Summer Programs was a repeat of the previous year's experience.

### Special Summer Programs

Of the 52 programs planned for the 1971 session, 10 had to be cancelled because of project low enrollments. There was a total registration of 1,220 in the 42 programs compared with a 1970 registration of 1,809 in 60 programs. The average registration per program was approximately the same as in the past two years.

In 1970, we attributed the decline in attendance primarily to the state of the overall economic climate; but some programs continued to remain quite attractive. This selectivity of the decline is further evident from this year's experience. Prior to 1970, the fields represented by the School of Management and the Departments of Electrical Engineering and Mechanical Engineering provided the largest component of the Special Program operation. It is these same areas which have experienced the most pronounced registration decline in the past two years. An important contributory factor would appear to be a reduction in R & D support (government and industrial) for some engineering and applied science fields. On the other hand, programs offered by the Departments of Civil Engineering, Nutrition and Food Science, and the Building Construction component of Architecture have continued to attract large numbers of registrants.

## Regular Subjects

Only a limited number of regular academic subjects are offered each summer. The 1971 registration of 2,197 represents little change from the 2,185 in 1970. Graduate students continue to comprise about 85 percent of the summer student body.

## Conferences

About 80 people attended the National Demand-Responsive Transportation Conference on July 12 and 13. This was sponsored by Project CARS of the Urban Systems Laboratory. Professor Daniel Roos was in charge, and Forbes Little was the Administrative Coordinator. In addition, there were special activities conducted by the Center for Advanced Engineering Study, the Education Research Center, and the Sloan School of Management.

## Project ADAPT

The Department of Urban Studies and Planning conducted an intensive orientation program during the entire month of August, 1971, for unemployed aerospace and defense personnel to prepare them for jobs in agencies of state and local government.

This pilot experiment was undertaken by Professor Lloyd Rodwin, Head of the Department. Francis T. Ventre was Project Director, assisted by members of the department staff. The program was sponsored by the Department of Labor and the Department of Housing and Urban Development and was one element of a nationwide effort of the National League of Cities and the U.S. Conference of Mayors. Of the 186 registrants, 30 percent came from Florida and Alabama; 20 percent from New York, New Jersey and Connecticut; and 50 percent from Massachusetts and New Hampshire.

The Project, known as Project ADAPT, included people of varying ages and educational backgrounds. Sponsors of the program hoped to match available talent with local management needs in the urban field. This matching began with on-campus interviews by prospective employers.

JAMES M. AUSTIN

## Upward Bound Program

The M.I.T.-Wellesley Upward Bound program is a coeducational, multi-racial, multi-ethnic educational program for Cambridge high-school aged youth. Now into its seventh year the program serves 60 academically promising girls and boys who have low achievement aspiration and who come from low-income families. The goal of the program is to motivate these youngsters to attend college and to additionally provide them with the necessary academic and social skills needed to succeed in college. To a very large extent the program is influenced by the research done by Kurt Lewin and his associates, particularly in the area of goal setting or "level of aspiration." The program has operated on the assumption that ego growth and academic performance are closely related, and has met with good success. A developing ego needs to experience success and it will develop more strongly, in both a personal and a social sense, in a warm personal but structured environment. This development can be manipulated through intervention outside of the family and the school. Upward Bound represents such a controlled field intervention. It has established that the effects of failure can be reversed by presenting the child with real success and that further success leads to an increase in the child's level of aspiration. In this process the people around the students play a crucial role -- both his fellow students and teachers and other program staff-- because what he thinks he can do is dependent on what they think he can do. Consequently his perception of his abilities, and therefore what he will try to accomplish, is to a large extent determined by the program staff, who are often the first and only people to see real academic promise in the youngster.

## Summer Program

The Summer residental program is designed to provide the student with an intense academic and social experience. Classes are team-taught by experienced high-school teachers and Wellesley College and M. I. T. students and Upward Bound alumni now attending college. Each Upward Bound student carries three classes each of which meets for 50 minutes, each day five days per week during the six-week summer program. Classes are small and of a seminar nature. Each student is required to take one math and one humanities subject and to select a third subject. Humanities offerings include reading and writing, black history, teenagers and the law, drama, moral philosophy, roles of women, anthropology, and college study skills. Science subjects from which the students might choose include astronomy, biology, man and his environment, topics in chemistry and physics, and intermediate science. The mathematics program includes an enrichment section for students who are going to take algebra II, geometry, or math IV; a review section for students who had done poorly in algebra II, geometry, or math IV; a computer math and a computer programming course sponsored by IBM.

## Academic Year

The academic year program, while ostensibly less intense and dramatic, has importance at least equal to that of the summer. Building on the motivation and enthusiasm developed over the summer, the academic year program is designed to help the student cope with the myriad academic, social, and family problems that confront him back in Cambridge. To achieve this, the following programs have been developed and implemented:

Study Skills The M. I. T. Upward Bound offices are open four evenings per week from 7:00 to 9:30 for study. Students are asked to spend at least one evening per week at one of these study sessions. Each session is manned by a team consisting of two leaders who are part-time staff and about four undergraduate volunteers. They work individually or in small groups with students on school related problems.

Tutoring Whenever requested or needed, tutors are assigned to individual students. Tutors are typically M. I. T. or Wellesley undergraduates who arrange to meet on a mutually convenient and regular basis with the Upward Bound student and then report back to the project staff.

## College Counseling

This year's graduating class included 22 seniors. Twenty of them will be continuing their education in the fall. One student will be entering school in January. Sixteen of these students will be going to four-year colleges. Four of the students will be going to two-year colleges with the intention of transferring into a four-year college and one student will be attending a pre-nursing program after which she will attend a nursing school or college.

College Enrollment

| School | No. Attending Fall |
|---|---|
| Boston College | 1 |
| Boston University | 2 |
| Emerson College | 1 |
| Fisher Junior College | 2 |
| Franconia College | 1 |

con't

College Enrollment (Cont.)

| School | No. Attending |
|---|---|
| | Fall |
| New England College | 1 |
| New Hampshire College | 1 |
| Northeastern University | 1 |
| North Shore Community College | 2 |
| Regis College | 1 |
| Salem State College | 1 |
| Simmons College | 1 |
| Suffolk University | 1 |
| Wellesley College | 1 |
| Wheelock College | 2 |
| Worcester Polytechnic Institute | 1 |
| | Spring 1973 |
| North Shore Community College | 1 |
| TOTAL | 21 |

## Saturday Program

The goal of the Saturday program is to furnish a miniature replication of the Wellesley summer experience. Students attend during the fall, winter, and spring on a regular basis on Saturdays from 10:30 to 4:30 at Wellesley College.

The Saturday program includes an arts and crafts class, drama, and a math class, as well as the use of the pool and gym.

## Wellesley—M.I.T. Exchange Program

Wellesley and M.I.T. students registered for a total of 1,317 subjects through the Wellesley-M.I.T. Exchange Program during the 1971-72 year, which marks the fourth year of a five-year experimental program first announced by Presidents Ruth M.Adams and Howard W. Johnson on May 17, 1967.

The purpose of this cross-registration program is to enrich and diversify the curriculum of both institutions. It has been very popular with the students on both campuses. During this fifth year, the entire experiment will be evaluated by a joint committee of both schools for the purpose of making recommendations for the future.

During the past year M.I.T. students registered for subjects in all Wellesley departments, the largest concentrations being in English and psychology with substantial numbers of students electing subjects in history, sociology and anthropology, education, art and

political science. Wellesley students took subjects in 21 M.I.T. departments. Approximately one-fourth of the subjects were in the humanities. The largest concentrations were in history and literature, while many students selected subjects in architecture, psychology, political science, biology, foreign literatures and linguistics, and planning and urban studies.

This year there was a residence exchange program between Wellesley and M.I.T. for about 25 students from each institution each term.

# School of Architecture and Planning

The School of Architecture and Planning focuses its concern on raising the quality of urban life. We are interested in a more human environment, one which is satisfying not only for the everyday life of all citizens, but also for a full range of experiences, including those which are aesthetically pleasing and spiritually fulfilling. Traditionally, the interests of the School have been in several areas: in the planning and design of the physical environment from single buildings to the urban scale; in social change and in achieving quality in the processes of environmental and social change; and in emerging and utopian ideas dealing with a better life and a better society.

Architects and planners whose skills are in the planning and design of the physical city have been the most numerous of those professionals who have graduated from the School. Now, however, we are also educating "housers," experts in the invention, analysis, and administration of this country's housing programs; we are beginning to build strength in health planning; and we have a growing number of students concerned with urbanization in developing areas of this country and elsewhere. There is a deep and pervasive commitment to serve those groups in society who are presently disadvantaged and voiceless. And there are many in the School who are interested in new kinds of social interventions and expression through new uses of the media and of art.

The impact of work by members of the School can already be seen in national and social programs, in state and local level planning practice, in the design of the near environment, and in the nature and quality of citizen participation. Their contributions in teaching and research have extended understanding in such areas as the planning and design of developing areas, the character of urban institutions and social programs, the analysis of urban form and experience, and the relationship between art and other areas of activity. In addition, many of our graduates find themselves in strategic positions at many levels in society, ranging from government agencies, to private organizations, to educational institutions across the United States. Despite the small size of the School for many years, we have had a disproportionately large influence on education, research, and implementation in the environmental and social fields.

In the last five years, the School of Architecture and Planning has doubled in size. The ratio of graduate applications to graduate admissions across all programs in the School averages ten to one. Enrollment by students in programs outside the School has increased proportionally. Because of this recent growth, the School is roughly equal in size to the School of Humanities and Social Science and the Sloan School. More than one M.I.T. student in 20 now has his primary professional allegiance in this School. Extraordinary shifts in membership in the School have also taken place over the last five years. The student body now comprises a much higher proportion of minority and women students than previously, and the increasing diversity in the background of the students is matched by the diversity of specializations among the faculty.

The past year witnessed several changes and events concerning the School's faculty and staff. Of special note here is the retirement of Dean Lawrence B. Anderson. The School was extraordinarily fortunate to have had Dean Anderson during the years 1965-71. His administration was characterized by gentle guidance, discreet suggestion, and

perceptive support. He continues to be greatly admired, emulated, and loved by those who have come to know him at M. I. T. Other changes and events of note within the Departments of Architecture and Urban Studies and Planning are discussed in the following reports by the individual department heads.

The past year has seen important educational developments in both of the Departments and in the School overall. The Department of Urban Studies and Planning has been broadening its fields of teaching and research to include many new and important areas of social and environmental planning. The Department of Architecture has been strengthening the teaching of its traditional core of architectural design, as well as new areas of the arts, especially film and photography. Both Departments are beginning to place emphasis on programs concerning the natural environment and the study of the processes by which the man-made environment gets built.

Joint programs have been developed between Urban Studies and Economics and between Urban Studies and Architecture. Additional joint programs with Political Science, the Sloan School of Management, and Civil Engineering may emerge in the very near future. The Community Fellows Program, under the leadership of Melvin H. King and Frank S. Jones, attracted a talented group of black and other minority professionals who spent two terms studying at M. I. T. The Special Program for Urban and Regional Studies in Developing Countries (SPURS) also attracted an outstanding group of mid-career professionals and educators, many having positions in the public life of developing countries. The Center for Advanced Visual Studies continued its interest in environmental and civic art, had several successful exhibitions, and expanded its teaching program to include several students from different areas of the Institute. The Rotch Library continued to build its collection as rapidly as its budget would permit in response to pressure from both new and well-established fields of interest in the School.

A School Council was formed during the past year to discuss issues related to the School's development. The Council consisted of Dean Emeritus Lawrence B. Anderson, both current department heads, two faculty members from each Department, two students, and myself. This group, in conjunction with the Chairman of the Visiting Committee, William E. Hartmann, selected "field-linked education" as the central theme for the 1971-72 Visiting Committee meeting held in March. The reason for this choice was the School's increasing concern and involvement in all aspects of field-linked educational activities. We had recognized that the point of direct contact between professional and academic experience is field-linked education--those activities which occur outside M. I. T. and which are tied to the students' academic experiences. During the past year, we began to look at our field-linked educational experiences in order to understand what educational needs professionals and professionals-to-be have, to help professionals recognize their need for educational resources, and to diagnose their own specific educational needs. Based on our experiences with field-linked education, we are continuing to explore the consequences of new thinking for the design of professional curricula in the School, for the introduction of new subject matter and forms of teaching, especially in the areas of human interactional and social process skills, for the introduction of new types of teachers and students into the School's programs, and for new configurations of public and private sector resources to meet educational needs in the social and environmental fields.

Despite generous backing from the M. I. T. administration, and despite the enterprise of many of the School's members, the School is struggling to fulfill its educational role. As new areas open up, there is little slack in the teaching budget to allow for further curricular development and the description of new research areas. New types of faculty and students in the School are posing new demands on the informal and formal administrative structures to accommodate them better and to allow them more involvement in and control over the School's processes. New teaching and research activities are requiring

new kinds of support services unprecedented in the history of the School. Moreover, space remains a crippling constraint, especially with respect to quality and location. Within the present budgetary and spatial limitations, we are having extreme difficulty in freeing the time of our most talented faculty and students for the purposes of pushing ahead and in creating the appropriate environment of support for new activities.

Nevertheless, we want not only to fulfill our current conception of our educational role, but we want also to look ahead in order to understand how that role should change. Society's demand for high quality in urban life is increasing. In responding to this increase, the institutions in our society are becoming more specialized and diversified. Issues of quality in urban life, including issues of the social and physical environments, are now being dealt with by public agencies at the Federal, state, and local levels, and by new types of consultant groups, land developers, and non-profit organizations. Many of the traditional planning and architectural firms are changing rapidly to adapt to new social needs and to their own changing conceptions of professional service. Some of the new specializations include social program planning and evaluation, architectural programming, and planning and design methods.

In any of these specializations, social interventions to improve the quality of urban life not only require skill on the part of the intervener, but may also require that the intervener be of the groups on whose behalf he is acting. This recognition has led the School to seek actively students from among groups it traditionally did not have or rarely had, especially among groups which have been economically disadvantaged. In turn, the School must continue its efforts to develop programs which will serve these and other students of art, architecture, and urban planning for whom our current professional degree programs may be inappropriate. Under consideration are specialized degree programs taking perhaps as little as one year to complete, as well as the development of educational patterns in which the student would work outside M.I.T. while attending classes on a part-time basis.

As the need for more diversified professional education is evidenced, so too is the need for new areas of paraprofessional and continuing education. The more people in our society who become involved with activities associated with improving the quality of urban life, the more opportunities at many levels of skill that will open up. There are many existing careers in urban planning, architecture, and civic art for which preparation does not require three to four years or even a degree. We are currently examining programs we might initiate in this large area of opportunity.

While increasing the range of individuals and of educational areas, however, the School must strive to help all its students achieve their own maximum growth and self-development. They must have not only the requisite knowledge, skills, and attitudes to be effective, but also an understanding (although not necessarily an acceptance) of the requirements for membership in the various private and public organizations in which they will work; they must have an ability to contribute to community values and to reform them now and in the immediate future; and, perhaps most challenging of all, they must have the capacity to grow and to adapt with integrity in a rapidly changing world.

Even though the path to these goals is not clear, I believe that if we remain ready to revise and replace not only our educational and research activities, but also our administrative procedures and postures, and if we receive the quality and amount of support we require, we can continue to build a community of excellence for education and individual development in the urban and environmental fields.

WILLIAM L. PORTER

# Department of Architecture

During the past year, the Department of Architecture began a fundamental reorganization, one that over the next several years will be reflected in all aspects of the Department: in student and faculty composition; in programs of teaching and research; in fundamental curricular structure and administrative arrangements; and in the relation of the Department to the School and to the Institute. The principal thrust of these changes has been to recognize and to give structure to a broader range of Departmental interests and responsibilities than has been articulated in the past.

We have recognized during this year a commonality of commitment to change in the relations between people and environments. At the same time we have recognized the diversity of means through which we wish to understand and to effect changes in the world that we see and touch. Architects on the faculty are concerned with illustrating possible new combinations of form, as well as developing patterns of design process and building technique that will enable more intelligent and useful communication to take place among architects, clients, community groups, and potential users whenever environmental change is proposed.

Filmmakers in the Department have developed an inexpensive new synchronized sound system that makes it possible for many people to become active in the making of film and to explore new uses of cinema documentation. In Creative Photography and in the History of Art, faculty have become deeply involved in the development of fresh ways of seeing and interpreting the images presented in photography, painting, and sculpture, and of understanding their relationship to the images we carry within. Studies rooted in the History of Architecture have extended into analysis of the structure of urban public spaces, and a group of faculty and staff has associated with members of the Urban Studies and Planning faculty to define their primary interests in environmental design around the problems of simultaneous change in the institutional and physical environments.

To give structure to this diversity, the faculty this year formed into clusters of common interest that were charged with defining research programs, organizing subject areas, counseling graduate students, and identifying candidates for faculty and staff positions. While this structuring is still fluid, there have already been several significant developments. These groups have been self-conscious about exploring shared directions, yet they have also become aware of possible links to other clusters and areas of interest in the Institute.

The Building Process cluster, for a portion of this year, assisted with the editorship of the periodical Industrialization Forum. Waclaw P. Zalewski participated in the design studios and helped design structural elements for the Built Form cluster's interest in the assemblage of environments from small parts. Edward B. Allen has also involved himself in several design studios and sponsored a conference in May on "Responsive House-Building Techniques" which brought together people specializing in various aspects of the field throughout the United States.

Further development of the School's computer lab, supported by a Ford Urban grant, has enhanced its capabilities to undertake research and to become a valuable resource for other areas of the Department. Missy Bush, a graduate student, has been working with Henry A. Millon on programming a library retrieval system for architectural drawings. Several students in introductory design subjects have also used the computer facilities as design aids.

As a balance to the advocating roles expected of the clusters, the Department established

an Educational Council to review curricular and staffing proposals and to develop policy guidelines with the department head. The Council worked very hard and played a significant role in establishing Departmental priorities and procedures.

The Educational Council this year consisted of six students and eight faculty elected by their colleagues. Members included: Frank Benesh, Victoria Haliburton, Michael Buckley, Vivian Loftness, Karen Wheeler, and Barry Zevin; Professors Wayne V. Andersen, Horacio Caminos, Robert O. Preusser, Chester L. Sprague, Waclaw P. Zalewski, Imre Halasz, Judith Wechsler, and Richard C. Tremaglio; and Benson R. Snyder, Dean for Institute Relations, who generously contributed his time to the efforts of the Council. In the spring term, Leon B. Groisser was appointed Executive Officer of the Department to assist with the preparation of meetings and the administration of the various programs. He has helped enormously to maintain order in the system. The Council has indeed proven to be an important forum for Department debate and discussion and, during the course of the year, we have learned much that can make the succeeding Council more effective.

A principal recommendation of the Council, subsequently adopted by the Faculty and the Corporation, has been the proposal to establish new degrees in the Department. The first professional degree, formerly the Bachelor of Architecture, has now been designated Master of Architecture, and the second professional degree is now called Master of Architecture in Advanced Studies. Programs leading to the latter degree will be reformulated during the coming year along with the development of proposals for Master of Science and Ph. D. degrees.

These shifts and proposed new programs recognize the development of new educational and career opportunities within the field and the necessity for a greater preponderance of research and theoretical support for the design professions. Two programs that serve as precursors of these developing patterns are the Graham Fellowships, which have brought Huck Rorick and Sean Wellesley-Miller to work with Nicholas P. Negroponte and the Architecture Machine group, and the Grunsfeld program in Urban Form Analysis which provides continuing support for the study of urban public space, including, this year, field studies in Paris conducted by 12 students and three faculty members during the January Independent Activities Period.

New patterns of professional training have also developed during the year and are under continuing study as part of a School-wide concern for establishing work-related educational opportunities. The intention is to provide an academic and field-linked process which integrates research and action. Several avenues for participation have already been developed: the Community Projects Laboratory which matches students with projects for community groups in the Cambridge-Boston area; John A. Steffian's design studios which have undertaken actual projects with specific clients and unusual requirements; and Chester L. Sprague's studies with American Indian groups which have introduced students to the complex problems of designing for unfamiliar cultures. The latter work has resulted in a summer study of Indian cultural activities centers which is supported by the Office of Education. Robert Goodman has been on leave this year, but his book, After the Planners, which was published this spring, has given voice to many important questions and concerns surrounding professional practice and the need for developing alternative forms of environmental action.

Another style of teaching this year tried to integrate a number of disciplines into a single subject or project. Dean Emeritus Lawrence B. Anderson taught an advanced studio this past term which focused on a large-scale library design based on a program prepared by Bemis Visiting Professor Colin St. John Wilson. Patrick Morreau taught a related structures subject, and Visiting Professor James O'Gorman taught a supporting subject

on the History of Library Architecture.

In response to our interest in pursuing a field-linked education program, faculty and student groups have formed to study various aspects of the problem. There will be continuing curriculum development throughout next year in consort with School-wide studies that are now under way.

In light of the above, it is important to note a developing pattern in our graduate admissions policy. With the energetic chairmanship of Chester Sprague, the admissions process worked very clearly this year even in the face of great numbers. For 20 places in the Master of Architecture program, there were 234 applicants. Students were admitted not only because of academic excellence, but also because of the particular combination of skills, interests, and background experiences they could bring to the Department. In presenting progress reports to the Educational Council for review at various stages, the Admissions Committee attempted to make the process reflect the goals and directions of the Department as a whole. The Department has also adopted conscious policies toward the admission of minority and women candidates and has attempted to make both admissions and financial aid procedures more explicit.

We have also restructured the introduction to the Department both for our own majors and graduate students and for the considerable number of undergraduates in the Institute who enroll in our subjects. The first year of the design course introduces students to major aspects of the field and to several ways of working on environmental problems. This year it was based on three studio subjects: Built Form I, Introduction to Environmental Design, and Building Projects Laboratory. Three other supporting subjects, conducted on a lecture basis, were organized to complement these and to allow students alternative means of entry into each area of study.

The success of these introductory subjects has led us to examine further possible ways of bringing students into the Department. The Environmental Arts cluster has devised an introductory subject, Creative Seeing, to be offered next year, that will consist of several study modules, each approaching the subject through different media. Judith Wechsler will introduce, with the cooperation of many disciplines, a new subject examining the aesthetic concepts inherent in the arts, sciences, and various technologies.

Finally, a more informal introduction to the Department through our extensive lecture series was ably arranged this year by Suzanne Weinberg. She worked hard to invite interesting and prominent speakers and to guarantee a good attendance by posting the colorful weekly calendar outside the Building 7 elevator on several floors. The Environmental Design Forum, a more pointed set of lectures and discussions sponsored by the Environmental Design cluster, served as an introduction to the concerns of that group and involved students and faculty from both Architecture and Urban Studies and Planning.

This year marks the official retirement of Gyorgy Kepes. The Department's debt to him is inestimable. He gave voice to the language of vision at M.I.T., and he has been an unforgettable teacher for generations of architects, planners, and artists who have known him or who have read his works. In the Center for Advanced Visual Studies, of which he will remain the Director, he has created a home for that special kind of creative imagining that reaches out into the city and touches the nature of our time.

DONLYN LYNDON

# Department of Urban Studies and Planning

During the past year, the Department expanded and diversified its student body, substantially augmented its faculty, and created additional ties to other departments and programs throughout the Institute. The formation of program groups, small clusters of students and faculty, brought those with common interests closer together. Program groups assumed major responsibility for student counseling, the development of curricula, the arrangement of special lecture programs, and the setting of research agenda. In addition, special attention was given to field-linked activities. Under the direction of our new Dean, William L. Porter, and Donald A. Schon, Ford Professor of Urban Affairs, we initiated a systematic review of all field-linked activities currently under way in the Department and the School.

We continued our efforts to involve students and faculty members in the formulation and review of departmental programs and policies. Ad hoc task forces and curriculum committees were set up to review policies and procedures regarding faculty recruitment, land use planning, social policy, public systems analysis and design, and supporting services (for students in need of special assistance). A number of special programs - some temporary such as Project ADAPT, others long-term such as the HUD Internship Program - proved quite successful. A number of research projects of significant size were also initiated. These and other activities reflect the major changes in the Department of Urban Studies and Planning, as well as the strong support we have received from the M. I. T. Administration.

## New Perspectives

*Program Groups*

The Department's Policy Committee was reconstituted to include representatives of each autonomously established interest group in the Department. Groups were also encouraged to nominate representatives to the Department's Admissions Committee, the School-wide Educational Council, the I. A. P. Advisory Committee, the Undergraduate Program Advisory Committee, and other ad hoc task forces. Students and staff were free to join more than one group. Fifteen student-faculty groups were organized on a formal basis and met regularly to sponsor special lectures, to prepare research proposals, to help "orient" new students, and to hold informal social gatherings. A small kitty was set aside to fund some of the activities of these program groups. The Undergraduate Legal Studies group, the Black Students group, the Environmental Design group, the Housing group, and the Regional Studies group were particularly active. Other clusters of students and faculty interested in Media and Communication, Health Planning, Income Distribution, New York City, and the Ph. D. Program met regularly to discuss their special interests.

*Revitalization of the Professional Program*

An effort was made this year to find ways of strengthening the professional degree program. We examined gaps in program offerings and faculty specializations in environmental design, city design, transportation planning, land use planning, and other aspects of planning in which spatial factors receive special consideration.

One pressing requirement, which will be met in part during the coming year, is the need to strengthen our capability in the area of natural ecology. Specifically, we have decided to place a new emphasis on: 1) the impact of current environmental policies and techniques for measurement; 2) the inter-governmental institutional constraints affecting the implementation of environmental policies and programs; and 3) new ways of determining

and measuring the special environmental and design requirements of various client groups, especially minority and underprivileged populations. To begin with, we are focusing on the interactions of urbanization and ecological systems and the development of tools for evaluating the ecological implications of land development policies.

Other areas selected for further development are problem-solving techniques, aimed primarily at policy synthesis, and the linkage of field work with classroom programs. Additional efforts will be required during the coming year to follow through on various proposals to meet these needs.

*Field-linked Activities*

There is a strong desire to break down the walls separating the university and the community. In the case of urban professional education, this is an imperative need, not an attractive option. This phase of our program, in the past, has tended to be little more than a scattered collection of workshops and field projects. We propose to experiment radically with this aspect of our education. We are aware, of course, of the explosive problems that often accompany efforts at community involvement, just as we are cognizant of the inadequacies of "studio exercises." Also, we want to design new devices that will help connect field experience and classroom learning. We intend to develop mechanisms by which we can evaluate and select field-linked activities most likely to benefit students and faculty. These efforts should help to heighten each student's self-awareness and to promote learning during the acquisition of field experience. Perhaps these improvements may even help to shorten the time required for the degree as students enhance their own abilities to learn in "field-linked" situations.

## New Programs

*HUD Minority Internship Program*

This year the Minority Internship Program funded by the U. S. Department of Housing and Urban Development and administered jointly by our Department and the Massachusetts Office of Planning and Program Coordination, involved 14 graduate students. Under the direction of Instructors Thomas Nutt and Alex Rodriguez the students spent 12 hours a week in government and community-based agencies. In general, these placements provided an opportunity for students to observe and participate in public policy development and implementation. Specific placements were made according to each intern's area of interest. Interns were placed in a wide range of different work settings including the Office of the Speaker of the Massachusetts House of Representatives, the Massachusetts Housing Finance Agency, the Governor's Citizens Committee on Corrections, the Spanish Alliance, the Roxbury Action Program, and the Boston Transportation Planning Review. A weekly seminar entitled "Planned Change and Implementation" was offered in conjunction with field placements. We have learned much from this year's experience. Next year, Professor William A. Davis, Jr. will be joining the faculty and will take over responsibility for an expanded Internship Program devoting special attention to linking the internship program to other components of the Department's curricula.

*Community Fellows Program*

The Community Fellows Program is finishing its first full year of operation. Established in 1970-71 to help minority leaders cope with problems of social and economic development within their communities, the program has brought a selected group of 11 men and women to M. I. T. for the academic year to work with members of the M. I. T. faculty on projects of special importance to the Fellows and to the organizations and communities they represent.

Under the leadership of Frank Jones and Melvin King, the Fellows met once a week for an

extended evening seminar. They divided their sessions between an exchange of information on their own projects and lectures by invited speakers such as Preston Wilcox, Rhody McCoy, Dr. Kenneth Clark, and Elma Lewis.

The Fellows are, without exception, active and involved community leaders. They found the program provided them with a helpful opportunity to review their past efforts and to focus attention on neglected or related interests and issues. Their projects and areas of study ranged from aspects of urban growth policy to minority business and low cost housing, cable television for black communities, and the problems of urban aid for black and Spanish-speaking communities. Next year, William D. Wright will teach a subject sponsored jointly by the Department and the Fellows program dealing with the telecommunications industry and opportunities for blacks and other minorities.

*Health Planning and Management*

There is a sizeable group of students and faculty in the Department seriously interested in the emerging field of health planning. At the present time interested students are served by the availability of a core curriculum in social planning and social policy and by several subjects offered in health planning. Michael L. Joroff's seminar on Fundamentals of Community Health Planning supported by the new Division of Health Sciences and Technology was an important addition to the curriculum in this field. This year discussions were initiated with the Sloan School of Management and the Division of Health Sciences and Technology in an effort to map out plans for a degree-granting program in health planning and management. This joint effort will continue through next year.

*Independent Activities Period*

This year, as last, the Department offered a series of "mini-courses" — intensive, week-long workshops and short subjects — in areas such as housing finance, grantsmanship, building systems, new town design, urban gaming, urban systems analysis, and rural community development. The mini-course concept again provoked tremendous enthusiasm. The intensive schedules and concentrated presentations were considered a great success and a useful supplement to the regular curriculum by most of the students. Under the direction of Professor Lawrence E. Susskind the ten mini-courses attracted over 300 students from all over the Institute. A group of students in the Department met throughout the spring to explore the possibility of sponsoring similar short subjects throughout the academic year.

## Students

*Undergraduates*

In line with quota restrictions imposed by the Institute-wide Committee on Curriculum there were 55 undergraduates enrolled in Course XI this past year. Eighteen students received S. B. degrees. In view of the experimental nature of the undergraduate program, students were selected in an effort to encompass as wide a spread of disciplinary leanings and future plans as possible. As a result, the undergraduate program includes students interested primarily in environmental sciences and engineering, as well as students who are concentrating primarily on social sciences. In addition to the undergraduates majoring in Urban Studies and Planning, we continue to serve a number of undesignated sophomores, freshmen, and a substantial number of students majoring in other departments.

*Graduates*

There were 61 Master of City Planning candidates enrolled this year (43 men and 18 women). Twenty-three of these students represented various minority groups. Ten students

received M. C. P. degrees in June and another eight are scheduled to graduate before classes resume in September.

There were 46 students enrolled in the Ph. D. program; of these, six were minority students. Twenty of the 105 graduate students in the program are foreign citizens. Five students received doctorates in June, and three are expected to receive the Ph. D. over the summer.

## Student Involvement in Departmental Affairs

Students serve on all committees and Task Forces in the Department with the exception of the faculty Executive Committee.

The Policy Committee is composed of students and faculty representatives selected by each of the fifteen departmental program groups. This committee meets weekly with the department head to discuss long-range, as well as immediate, concerns such as faculty hiring, admissions and financial aid policy, and issues related to curriculum development.

Ad Hoc Committees on Curriculum Development included eight committees appointed this year to examine program and curriculum development options in social policy, environmental design, land use planning, urban and regional economics, developing areas and regional planning, and the analysis and design of public systems. All interested students were given an opportunity to serve on these committees.

The Appointments Committee was established last fall to evaluate and screen potential candidates for faculty appointments; to make recommendations to the Executive Committee and the department head for improving recruitment procedures, particularly those directed toward identifying younger and minority candidates; and to develop procedures and guidelines for the processing of candidates for reappointment, promotion, and tenure. This committee is composed of the department head, two tenured faculty members, two elected non-tenured faculty members and two elected students.

The Admissions Committee includes four separate committees each composed of three students and three faculty. The Committees reviewed over 550 applications to the M. C. P. and Ph. D. programs and selected the incoming class of 45.

The M. C. P. Monitoring Committee is responsible for monitoring the progress of M. C. P. candidates in the Department. Its responsibilities are two-fold: to review each student's proposed program of study; and to monitor each student's academic performance. The committee includes four faculty members and three students.

The Ph. D. Monitoring Committee periodically reviews and sets guidelines for curriculum coverage in areas of specialization and monitors the Ph. D. guidance process. This committee also provides a forum for discussion and evaluation of the Department's teaching program and the Ph. D. examination process. Four faculty members and two students serve as members.

## Financial Aid

Ninety-one of the 100 graduate students requesting financial assistance from the Department received a total of $400,000 (approximately tuition plus $200/month). The Department was selected by the American Society of Planning Officials - Ford Foundation School Selection Committee to receive a $10,000 grant for each of the next two years to support minority students in the M. C. P. program. A special $1,500 grant was also received from the American Institute of Planners Foundation to provide scholarship support for undergraduate minority students.

## Minority Recruitment Program

A special effort was made this year to broaden the range of minority students in the graduate program. Recruitment trips to the southwest and the west resulted in the inclusion of four Mexican-American students, one Puerto Rican, and one American Indian, along with twelve black students, in the incoming class. Thomas Nutt handled the recruitment efforts and deserves special recognition for his efforts.

## Faculty and Curriculum Development

*Social Policy*

Under the leadership of Professor Martin Rein students and faculty interested in topics such as income distribution, welfare policy, health-care delivery, manpower planning, and various social service strategies have focused their concerns and have begun to organize portions of the curriculum dealing with questions of equity and redistribution. The social policy group has spent a good portion of its time this year exploring areas of common interest with members of the Departments of Economics and Political Science at M. I. T., and with the Kennedy School of Government at Harvard University, the Florence Heller School at Brandeis University, and the new Harvard-M. I. T. Program in Health Sciences and Technology. Professor Rein's seminar on "The Impact of Public Policy and Income Redistribution on Social Stratification" provided a focus for the consideration of public policy arguments in favor of income redistribution and equity as central social goals. In the area of health planning a team of faculty members led by Professor Robert Hollister and Michael Joroff helped to lay the groundwork for a joint program with the Sloan School of Management and the Division of Health Sciences and Technology. Next year with the addition of Lecturer Robert G. Buxbaum and Assistant Professor Thomas R. Willemain, we will offer a strong core of new subjects in the health planning area.

Our work in social policy will focus on health planning, housing, and manpower. A special effort will be made in the coming year to develop a core of subjects in social policy which will build on a series of analytical and methodological concerns in policy analysis.

In cooperation with the Department of Political Science we received a five-year extension of our grant from the National Institute of Mental Health. Under the direction of Associate Professor Robert M. Fogelson and Michael Lipsky, Associate Professor of Political Science, the two Departments will offer a special sequence of subjects dealing with issues of mental health and organizational change.

*Environmental Design*

Professor Kevin A. Lynch and Assistant Professor Gary Hack worked with members of the Urban Design group in the Department of Architecture to organize an interdepartmental program in environmental design. A number of new subjects were offered this year including Graphic Communications (Associate Professor Tunney Lee); Community and Regional Planning Methods (Associate Professor Philip B. Herr and Lecturer Stephen Carr); Environmental Programming (Assistant Professor Michael O'Hare); Psycho-Social Impacts of Technology (Stephen Leff, Harvard Medical School); and Introduction to City Design and Environmental Planning (Assistant Professor Gary Hack).

We continued our efforts under the leadership of Philip Herr and Stephen Carr to develop a local citizen planning capability in the Cambridgeport community. In addition, Michael Southworth and Kevin Lynch continued work on a number of projects dealing with the educative qualities of the central city.

Next year, Lecturers John Stainton and Walter Bogan and Assistant Professor Robert Yin will join the Environmental Design group.

*Housing, Community Development, and Urban Economics*

Visiting Professor Philip David and Assistant Professor Arthur Solomon helped to augment the Department's faculty in the housing field. New classes in the Construction of Housing (D. Quinn Mills, Assistant Professor of Management), Urban Land Development (Philip David), Housing Analysis and Public Policy (Arthur Solomon), Advanced Housing Seminar (Philip David), Poverty, Urban Employment, and Manpower Planning (Arthur Solomon), and a full-year sequence in Issues and Strategies in the Community Development (Lecturer Melvin King and Professor Frank Jones) substantially extended our offerings in this field.

Professor Bernard J. Frieden, who was appointed the new Director of the Harvard-M. I. T. Joint Center for Urban Studies, announced that the Center will focus primarily on housing and housing-related issues. For the coming year, Associate Professor Bennett Harrison, Associate Professor William A. Davis, and Assistant Professor William Wheaton will join the faculty and will help to develop more specialized classes in inner city economic development and land economics.

*Analysis and Design of Public Systems*

The appointment of Assistant Professors Richard Larson and Joseph Ferreira helped to strengthen our ties to the Operations Research Center and to build up our specialization in the public systems area. Subjects in this field introduced this year include: Analysis of Public Systems (Joseph Ferreira) and Decision Theory and Policy Analysis (Michael O'Hare and Richard Larson). The School-wide office of Computer Services expanded its program as Research Associate Charles Libby and Lecturer Wren M. McMains developed a variety of tutorials for students interested in computer applications in urban studies and planning.

For the coming year, Alvin W. Drake, Associate Professor of Electrical Engineering, will work on a joint project with Joseph Ferreira on Formal Modeling. The addition of Associate Professor Bennett Harrison and Associate Professor Karen Polenske to our staff will add depth to our work in this area. Under the direction of Professor Aaron Fleisher, the Public Systems group has expanded and reorganized its portion of the curriculum and attempted to develop new ties to the social policy group as well as other groups in the Department.

*Developing Areas*

Now in its fifth year, the SPURS program brings together a dozen individuals from various developing countries. Participants this year represented fields of interest including housing policy in selected African countries, environmental research, and urbanization in the Amazon region of Brazil. A special two-day seminar on "Autonomous Housing Action in Brazil" was held in December. During the spring term, three study groups presented day-long reports on the socio-economic impact of technology, environmental aspects of technology, and implications of technology for planning, organization and decision making in developing countries.

Over the next three years, the Ford Foundation will provide the support necessary to help incorporate the SPURS program into our regular departmental curriculum. Next year Assistant Professor Donald I. Terner will serve as co-director of a new research project on Housing Technology Transfer and will teach a year-long seminar with Lecturer John F. C. Turner on the problems of self-housing and housing technology in developing areas. In addition, Instructor Shoukry Roweis will teach a graduate seminar on comparative urbanization.

We are presently revising the curriculum dealing with developing areas. This revision will affect not only the regular degree programs but the Special Program in Urban and Regional Studies (SPURS) as well. We are emphasizing national policies for regional and urban developments, social aspects and consequences of these policies, particularly migration, and special problems of low-income and migrant settlement. In the future it will be made clear that the bulk of any Fellow's program will consist of regular course-work. This past year, we failed to make this requirement clear and it created mis-understandings. In addition to this change, we are seeking to integrate Fellows more fully into the life of the Department.

Special research efforts focused around the development of a national and regional simulation model for the United Nations to be used to evaluate and predict the impact of alternative growth strategies. Also, we helped to explore possible collaborative efforts with key leaders in countries such as Iran, Portugal, Mexico, and Yugoslavia.

Earlier in the fall, Visiting Lecturer Ivan Illich led a special two-week series of seminars. Illich, well-known for his controversial views on education and de-institutionalization added a lively dimension to our discussions of educational strategies for developing nations.

## Research and Publications

*Boston Development Strategy Research Project*

At the end of March, we received some seed money from the Urban Systems Laboratory to explore some of the problems involved in devising alternative development strategies for the Boston region. As a first step in the process of articulating the principal components of a politically feasible and economically viable development strategy for the region, a series of 23 research papers focusing on a wide variety of issues were commissioned. Seminar participants were asked to examine the determinants of the quality and scope of services in the region, to evaluate the implicit policies underlying the operation of existing programs, institutions, and service delivery systems, and to identify alternative policies and institutional structures. Each researcher was also asked to examine the implications of their recommendations for Federal, state, and local policies and to spell out critical researchable questions or hypotheses suggested by their studies. We held ten informal seminars throughout the spring to allow researchers and critiquers from government and the private sector to confront one another on the critical issues of regional development and to begin a synthesis of policy proposals. A final project report entitled The Boston Development Strategy Research Project is being published by the Urban Systems Laboratory.

*National Urban Growth Strategy*

The Federal government has only recently confirmed its interest in deliberately influencing national patterns of urban growth as a way of achieving social and environmental objectives. If this emerging national policy is to have a sound underpinning, a good deal of research will be necessary to design and evaluate alternative growth strategies. Relationships between inner cities and suburbs, between depressed areas and regions experiencing rapid growth, and between urban areas of different sizes and densities will have to be understood much more clearly if we are to formulate policies aimed at reducing present disparities. Through a small Ford grant to the Department (part of the larger Ford grant to M.I.T.) the Department initiated a research study under the direction of Lloyd Rodwin and Larry Susskind. Papers on new communities, national land use policy, and inner city economic development have already been completed, and research proposal designs to expand our work in this area have been prepared.

*Project ADAPT*

An orientation program for 200 unemployed aerospace and defense personnel took place at M. I. T. last August. The summer program was the first phase of a larger effort aimed at transferring some of the relevant analytical technology of the crippled aerospace industry to the management of urban affairs. The project was sponsored by the U. S. Department of Labor and the Department of Housing and Urban Development and was conducted by the National League of Cities/U. S. Conference on Mayors. Under the direction of Research Associate Francis Ventre members of the Department designed and implemented a four-week orientation program, and undertook a comprehensive evaluation of the program's impact on the attitudes, abilities, and job prospects of the enrollees. The "instruction" was by no means limited to formal lectures. In an effort to sensitize the participants to various aspects of the urban scene, ADAPT sent program enrollees to 16 communities in the Boston area to talk with residents, store owners, and political figures. Film programs, as well as computer-aided simulation and gaming sessions, were designed to give the participants a multi-media exposure to a full range of urban issues and problems. By the end of June, more than 50 per cent of the ADAPT enrollees had been placed in urban-related jobs.

## The Educative Environment

Faculty and students in our Department have for several years been developing ideas and techniques for managing environmental quality in regions and cities. We have been concerned particularly with the tangible, visible aspects of the urban setting and the way in which its space and patterns of activity communicate meanings, or directly support what people want to do, or give them delight and satisfaction, or reinforce their sense of community, or stimulate their children to learn and mature. These critical qualities, difficult to define and usually impossible to quantify, have been generally disregarded in the design or control of the physical environment, especially at the larger scale. We have attempted to remedy some of these problems by developing experimental alliances with public and private institutions responsible for creative work in these directions.

We are also trying to demonstrate some of the educative potentials of city environments. These efforts encompass an urban travel program for youth designed to create learning opportunities in the public transit environment, investigations of the innovative educational possibilities for new communities that draw on the whole environment and the process of making it, and a program for the Lowell, Massachusetts, Model Cities agency for developing the canals and mills of Lowell as learning settings.

## Other Activities

Boston area alumni held a reunion dinner at M. I. T. in April. The group sought to identify new ways in which they might draw upon and contribute to the Department's resources. Preliminary suggestions have included: 1) more opportunities for continuing education; 2) greater emphasis on student training and placement in community agencies; and 3) assistance to alumni engaged in public service. An alumni seminar on "The Future Character of the Urban Fringe" was also held in the spring. Public and private sector planning experts and members of the faculty led seminars examining the factors which shape suburban development. A larger meeting of alumni is being planned for October when the American Institute of Planners will hold its annual convention in Boston. We have also continued publication of our Alumni Newsletter in an effort to keep alumni up to date on departmental activities.

At the undergraduate level, we initiated a new tutorial program designed to bring students and staff members into close working relationships around commonly held research interests. Twelve undergraduate tutorials were arranged this year, each with a faculty

member and three or four students. They met on an informal basis in an effort to provide special opportunities to explore areas not covered by the regular curriculum and to supplement the faculty advisory system. Continued efforts were made to link our Department to other activities around the Institute. Lloyd Rodwin served on the U. S. L. Steering Committee, an AID Advisory Committee, and the Educational Policy Committee for the School of Architecture and Planning; Lawrence Susskind replaced William Porter as a member of the Corporation Joint Advisory Committee; John T. Howard served as a member of the Graduate School Policy Committee; John Harris served on the Institute's Environmental Policy Committee; Lisa R. Peattie was a member of the Committee on Educational Performance; and Ralph A. Gakenheimer served as a member of the Committee on Curricula. In recognition of their many contributions to the Department as Assistant Directors of the Undergraduate Urban Studies Program, Leonard and Suzann Buckle received the Baker Award for outstanding teaching.

## Future Needs and Prospects

We have initiated a new phase in urban and environmental studies at M. I. T. The first phase involved the end of narrow specialization. It is not over yet, but clearly the shackles of professional provincialism have been broken. Increasingly, our multi-disciplinary approach incorporates the perspectives and tools of anthropologists, political scientists, sociologists, economists, operations researchers, specialists from management, and technologists from the "harder" sciences. The mushrooming undergraduate program — only two years old — is spurring the transformation of the graduate program. There is growing sophistication concerning the use and importance of field-linked activities. There is a heightened interest in new approaches to evaluating issues of social and environmental policy, to program implementation, and to client-oriented analysis.

Our Department is attracting first-rate students and faculty and is currently, at least in the scale and variety of its efforts, one of the two or three most respected programs in the country. What is more, we are a focal point at M. I. T. for concern with the problems of minorities and disadvantaged groups.

We have successfully mustered the resources necessary to increase minority faculty members, to ensure adequate financial aid for each student, and to build up some of the necessary administrative infrastructure of the Department. Over the next year, we will focus on the development of a core curriculum, cutting out less important aspects of the curriculum and selecting a few areas of special interest on which to focus resources. We hope to reorganize the professional degree program especially in the area of land use planning. The demand for professionals skilled in environmental analysis and large-scale environmental design is increasing, and we hope to take the lead in redefining the skills and concepts that the land use and environmental planner of the next decade will need.

We also plan to give careful consideration to the merits of a one-year degree (Master of Science in Urban Affairs) for students interested more in community organization credentials than in the professional planning degree. An additional concern over the next year will be the further development of the research activities of our Department.

As the undergraduate program continues to grow we hope to experiment with new approaches to undergraduate education. To some extent, this will mean an expansion of the Undergraduate Research Opportunities Program and the Undergraduate Field Service. We are also exploring possible collaborative efforts with the Education Research Center around a number of "unified studies" programs for undergraduates interested in environmental planning.

Two additional tasks will also receive special attention during the coming year: the development of more effective ways of evaluating teaching performance and of evaluating

field-linked activities and the role they ought to play in the professional curriculum. We also plan to strengthen our ties to research centers and governmental agencies in other countries through which our students and faculty might contribute to the formulation of growth strategies, to a better understanding of the potential of technology transfer, and to a more careful analysis of the social policy implications of alternative urbanization strategies in developing areas. One other idea raised during the year will also be pursued: the creation of an Adjunct Professorship or some equivalent which will allow us to attract top-notch practitioners to work with students in the field both in this country and abroad.

In general, we expect the next year or so to be a period of careful and continued self-assessment as we try to redevelop and update the curriculum to reflect the changing demands professional planners are likely to face over the next decade.

LLOYD RODWIN

# School of Engineering

Engineering education in the United States and at M.I.T. is without doubt in a dilemma. Since World War II, it has changed from a strongly professionally oriented education, with an emphasis on "knowing how" in specific engineering fields, to one having a strong emphasis on individual scientific disciplines.

This change was triggered by the realization that during World War II the "how to do" engineers did not have a sufficiently broad base to cope with the challenges of radically different and new advanced systems. Development of the engineering sciences was further encouraged by the Federal government during the 1950's and 1960's through major support of engineering-science research. Finally, students were encouraged to follow this new trend since the engineering-science graduate found ready employment in "advanced technology industries" supported by the Department of Defense and the aerospace programs, or as teachers of engineering sciences in the academic institutions.

The increasing complexity of our society and its dependence upon the application of technology make it apparent that applying technology wisely for the true benefit of society requires a multidisciplinary approach and that engineering education must undergo further changes to meet new needs. However, while engineering education is faced with this challenge to develop new types of engineers to meet the broader needs of society, it is simultaneously faced with serious restraints. The last few years have witnessed a remarkable change in the attitude of the general public toward technology. This source of our present strength and well-being now is blamed for our polluted air and water, the problems of our cities, the all-too-rapid increase in world population and many other problems, accounts of which now are featured prominently in the media. These accounts, coupled with the current unemployment of some engineers resulting from changes in our national priorities for defense and space programs, have influenced many high-school graduates with the talents to become very successful engineers to turn to other fields. This is tragic since meaningful applications of technology must play a crucial role in solving the major critical technology-related problems of society, as well as many of its other problems.

We see a sharp curtailment of government funding for special applications of advanced technology such as required in the space and military fields. We also see the position of important segments of American industry weakening as a consequence of their neglect during the past 20 years as Federally sponsored, high-technology application areas were favored. Today, the nation faces unemployment in engineering, but there is no doubt that a society which is so strongly dependent on technology continues to need engineers. The dilemma for engineering education is that it should develop engineers for the future -- not engineers to meet the demands of yesterday or today. The identification of the type of engineering needed for the future must therefore precede the development of specific plans for engineering education.

Engineering has played a service role to society from its beginning. Its scope has changed over the centuries and has undergone dramatic changes in recent decades. Analysis of this development provides insight into the challenges which engineering faces today and will face in the future -- challenges which must be faced squarely by engineering education.

Engineering was, from its earliest phase, concerned with the creation, and in some cases the operation, of man-made physical facilities to meet the needs of society. It depends heavily on the advancement of the general science base on which it draws and builds in order to develop the more application-oriented engineering-science and technology bases.

Historically, the initial concern of engineering was with hardware such as with machines and structures. Later the concern was with combinations of machines and structures. Examples from this first era include the development of motors, farm machinery, transformers, blast furnaces and buildings; combinations of components are exemplified by ships, electric power plants, railroads and telephone systems. In all these cases, the original concern of the engineer was with the engineering feasibility of the structures and machines and their adequacy for the purposes for which they were developed. The designer, naturally, was also interested in the cost of producing his product. Thus, the value structure for the engineer consisted of technical feasibility and product cost.

As society became accustomed to an increasing application of technology, even demanding more applications of technology, it became necessary for the engineer to add new dimensions to his thinking. He had to see the individual products of engineering in the context of the operational systems of which they were integral parts. Suddenly the naval architect saw the ship not just as an individual operating unit, but also as a component in a transportation system. Thus he had to become concerned with port development, related land transportation, and labor problems. The aeronautical engineer suddenly saw the airplane not as just an intricate flying machine, but also as a part of the air transportation system. Then he became concerned with airport design and access, as well as air-traffic control and utilization of resources -- planes, pilots, etc. The chemical engineer saw the individual processing stages in a chemical plant as part of the total dynamic chemical processing system which includes the supply of raw materials and the demand for and delivery of finished products. These changes were closely coupled with the rapid development of systems analysis and operations research, as well as the development of information processing, optimization techniques, and control systems.

Now it was necessary to apply the cost factor in the engineering value structure to a much broader base. It was the performance of the overall system (measured in terms of cost) which counted, not the optimum performance of each component.

This value structure is now expanding once again as society demands an evaluation of the impact of technically based projects on the natural and social environment. That is, an evaluation of the social costs. Consequently, in addition to the technical feasibility and the cost as just described, the social feasibility and cost must now be included in the considerations of whether or not to undertake a project such as the installation of a new power plant.

How are these changes in the value structure affecting the scope and attitude of engineering? A careful analysis of this development of engineering will provide important perspectives from which the role that engineering must play in the future can be outlined. It will also help to identify new challenges for a forward-looking engineering educational program.

The engineering process has traditionally been based on the engineering-science and technology bases from which concepts and design for technologically feasible components and systems are developed in response to the needs of society. After the factors affecting implementation are evaluated, the development of actual engineering components and systems begins with a process described by the phrase "design in order to build."

Today society is at the stage where a process described by the phrase "develop concepts in order to decide what to design" is rapidly gaining importance for the following reasons:

1. Each technological solution which a society accepts changes the outlook and value system of the society; and

2. Due to society's increasing dependence on technology, our operating systems (transportation, energy supply, material supplies, communications, etc.) have become extremely complex and interdependent.

In order to cope with the process of developing and evaluating concepts for technologically feasible systems two new types of efforts are required. They are needs analysis -- the process of clarifying the real needs; and impact analysis -- the process of determining the impact of any proposed solutions.

It does not take long to realize that most frequently the statement of a need is a statement of a preconceived solution. Consider as an example the actual need to solve the problem of the slums. Most frequently, when this topic comes up, the need is stated in quite a different fashion; for instance, as the need to develop low-cost housing. In this particular case, it becomes quite apparent that only the combination of low-cost housing and the creation of employment opportunities, combined with social development, offers hope to resolve the actual problem.

More generally, then, a needs analysis has as its aim the identification of the actual needs, as well as of meaningful approaches for developing total systems concepts for meeting these actual needs. Engineers must participate actively in this effort because their model-building abilities and systems-analysis approach can contribute substantially to needs analysis. And the aptitude of engineers to respond with technical innovations can help to identify, at an early stage, concepts for new, meaningful solutions.

The other new effort, the impact analysis, is concerned with the impact of technologically feasible systems on the environment, the economy, and the society. Such studies can only be effective if the engineers, in participation with social scientists, economists, and others, analyze these impacts, including such broader aspects as the impact on individuals and groups (and their aspirations), on existing institutions, on the nature of government, on policy making, etc. Impact analysis will become a uniquely important and critical process in our future development of technology and its application. It identifies:

1. Alternatives and their consequences as a factual input into decision making;

2. Areas of research and development that are critical for developing new solutions;and

3. Regulations, legislation, policies, and organizations that must be developed or adjusted to make meaningful solutions become a reality.

In summary, the evolutionary process which expanded the scope of engineering grew from an initial "hardware phase" concerned with developing and applying engineering-science technology bases, through engineering products seen as parts within operating systems (with a corresponding change in evaluating costs of optimum performance), to the introduction of the concepts of quality of life and of social and environmental values by needs and impact analysis. Thus, the emphasis is not on "Is it technologically feasible?" but, rather, "Does it make overall sense?" And, finally the scope of engineering must include a concern to making meaningful solutions socially and politically feasible. It is clear that other fields, such as economics, management science, and political science, must enter into the total process.

The expansion of the scope of engineering beyond the engineering-science and technology bases and the hardware phase can be described as the introduction of the "software phase" which relates to systems and to concept analyses, the need and impact analyses, and the

identification of action and policy alternatives. As we progress through the stages of this "software phase," we see a systematic way for developing a constructive approach for applying technology to meet society's needs in a meaningful manner.

This approach -- needs analysis, development of concepts, impact analysis -- is aimed at developing action alternatives and identifying their short-and long-term consequences, as well as steps toward implementation. It will increase society's options in the application of technology and will illuminate rather than eliminate major decisions facing society. It establishes a new role of professional service in which engineering must participate in a leading manner by providing a service to the decision-making elements of society.

This broadening of engineering and its activities establishes a challenge for engineering education as the need for four distinct types of engineers emerges. To a first order approximation they can be characterized as follows:

1. The technologist whose main concern and interest are with the existing technology in the fabrication, operation and maintenance of engineering products and industrial processes. This education requires background in the related sciences and the development of basic skills in his field of technology, coupled with an understanding of industrial practices in his field.

2. The practicing engineer and designer whose main concern is the application of science and technology in the conception and development of new "hardware." His education requires development of a strong background in related engineering economics, as well as the development of capabilities for synthesis.

3. The engineering scientist whose main concerns are the advancement of the engineering sciences and the laying of the foundation for new technology. His education requires development of a strong background in related sciences, as well as the development of research abilities.

4. The broad systems engineer whose main concern is the determination of the broad design characteristics for meaningful systems to meet actual needs of society. His education requires the development of a strong foundation in engineering and systems analysis, as well as the development of capabilities to relate engineering solutions to society's needs.

All four types of engineers will be crucial in developing effective uses of technology for the good of society. There are common elements in the educational development of these four types of engineers, but the relative emphasis must differ substantially from type to type. Programs in engineering education must continue to build on a meaningful engineering-science base, but they must recognize that the base must be tailored to meet the needs of the particular student for specialization or generalization. However, this engineering-science base, mandatory as it is, is not in itself sufficient. Engineering programs must offer students, again depending on their particular interests, opportunities to develop a capability for synthesis, familiarity with current technology, and the ability to work at the applications interface between technology and society. They should strive to develop not only knowledge, but also insight and understanding. They should be coupled to the real world in such a way that the student gains the ability to identify and define problems, as well as the ability to develop meaningful solutions. Finally, these new engineering programs should provide links with the real world and the practicing profession.

Engineering education must emphasize that the overriding motivation for engineering is the development of meaningful solutions, and it must foster the development of the engineering attitude to produce practical, but not necessarily perfect, solutions within the constraints

of time and costs.

This, then, is the statement of our goals. But what of the School today. I am happy to report that the School of Engineering is very much alive; our undergraduate enrollment has held reasonably constant over the past two years; the total number of graduate students is continuing to increase slightly; and the research program of the School is healthy and growing. This record, in itself, is impressive.

During the past year, we have seen more of the School's faculty become interested in less formal modes of teaching. These include the faculty's offering of undergraduate seminars, as well as their willingness to have undergraduate students assist them with their research projects or for the student to conduct his own project under their supervision. We estimate that 500 students, many of them freshmen, participated in seminars offered within the School of Engineering during the past academic year and that upwards of 400 students were involved in research activities within the School. In addition, a large number of students were involved in similar activities during the Independent Activities Period.

While significant numbers of our faculty are becoming increasingly involved with teaching and research at the interface between technology and society, as I shall discuss shortly, we recognize the importance of continuing our efforts at the cutting edge of engineering science and advanced technology. Mention of a few highlights will illustrate the vitality of work in these areas. Project MAC, which deals with the evolution and use of very large computer systems, is flourishing. Secondly, a new project on enzyme technology was launched by the Department of Chemical Engineering, together with the Departments of Nutrition and Food Science and Biology. Faculty from many departments in the School are deeply involved in the application of engineering to bioengineering and health care.

Pioneering work in the area of superconducting machinery by faculty and students in Electrical Engineering and Mechanical Engineering is illustrative of our efforts in the area of advanced technology. Ultimately these developments should find wide application in the energy field.

I am particularly pleased to report that, building on our strong and growing base of engineering science, the School has in the past few years increased significantly both the research and activities related to civilian applications of technology. These developments take advantage not only of recent advances in the engineering sciences, but draw as well on such areas as operations research, systems analysis, and applied economics. A few examples of the type of evolution now underway will serve to illustrate this development:

1. Out of the Department of Civil Engineering's Hydrodynamics Laboratory has grown a strong water resources development program which integrates a wide range of engineering disciplines with inputs from the "soft sciences" to develop programs to help meet the crucial need for water.

2. In Ocean Engineering, the program in naval architecture and marine engineering has evolved into a program for marine transportation. This program does not focus narrowly on naval vessels but considers ocean transportation in the context of the movement of commodities, the related operations at ports, and the interfacing of marine and land transportation into a total economic system.

3. The Department of Aeronautics and Astronautics has, in a similar way, broadened its horizons and now has strong efforts directed toward study of the complete air transport system including aircraft safety, airport development and air traffic control.

4. The Department of Electrical Engineering jointly with the Department of Mechanical

Engineering has a healthy and growing program in electric power. Efforts under this program, which has close coupling with industry, range from consideration of advanced systems for the generation and transmission of electrical energy and the dynamics of distribution systems to study of trends in the demand for electric power and the total technical-economic problems related to meeting that demand.

These are just a few examples of how the engineering science and technology effort has been expanded to include meaningful applications of technology to real world problems. Now we are standing at the threshold of a new and exciting development; development which is aimed at taking great advantage of the resources of the individual departments. Let me illustrate by three examples:

1. Three separate groups within the School of Engineering which concentrated respectively on air, land and sea transportation, realized that they would be more effective and stronger if greater cooperation and interaction could be achieved among them, and if the research and teaching were supplemented by systematic studies of the broader issues of transportation. I refer here particularly to the interaction between transportation, economic development, and urban planning. I am happy that I can report that a task group of about 40 faculty members (30 from the School of Engineering and the remainder from other Schools at M.I.T. and from neighboring universities) will explore, this summer, ways to foster the interaction and integration which they all agree would be highly desirable.

2. Recently, the Engineering Council formed a group to explore ways of establishing an umbrella organization to foster more effective interaction between the various strong research efforts in the School of Engineering which concentrate on generation, conversion, and transmission of energy and, particularly how these efforts could support a proposed new effort which will concentrate on basic considerations relating to the energy issue. Here, I refer to the needed expansion of research on such questions as energy supply and demand, meaningful uses of energy, and study of trade-offs between the alternatives of attempting to meet the increasing project demands for energy, or developing means to temper this growth of demand through more effective energy utilization.

3. The efforts of many faculty members in the School of Engineering which were initially aimed at the scientific aspects of pollution research are now being directed more toward consideration of combined technological and regulatory means for controlling pollution. But above all, it is most gratifying to observe that environmental considerations are becoming an integral part of the value structure of engineering and of the design process. Current approaches to the planning for and design of nuclear power plants, tankers, aircraft, and highways demonstrate this point.

These examples have illustrated the broadening of the value structure of engineering currently underway, and the steps taken by the School to enlarge its scope in order to pioneer in covering broader spectrums of concern demanded of the engineer of the future. They illustrate that we continue to draw our strength from engineering sciences and advanced technology and that we can continue to develop these frontiers. I hope they illustrate just as clearly, that we are systematically searching for meaningful applications, not only of advanced, but also of existing technology. And, that we are determined to gain our experience by actually working on real world problems in cooperation with other Schools at the Institute, a cooperation which we actively seek.

During this exciting period in the development of the School of Engineering, we naturally face a number of difficult problems. In the past few years, we had to learn to work with new sponsors such as the Environmental Protection Agency, the Department of Transporta-

tion, and the Department of Health, Education, and Welfare, to mention a few. This transition has required major efforts and extensive and complicated negotiations. It appears to me that we are about to master this problem to a considerable extent. Another problem stems from the fact that many of these interesting new programs are not confined to the structure of existing departments in the School of Engineering and in many cases, of the existing schools at M.I.T.; research on these broad societal problems requires strong interaction among the participating faculty. We are searching for mechanisms to carry out broader research and the related education programs. Two examples which illustrate the progress which we have made in this area can be cited:

1. In 1967, the M.I.T. Sea Grant Program started with a $70,000 grant to be expended over a two-year period to develop five textbooks in ocean engineering. This program expanded first within the School of Engineering and has now become an Institute-wide activity focusing on ocean utilization and coastal zone development. It has an overall budget for FY 1973 of slightly over $1 million with $600,000 being provided by the National Oceanographic and Atmospheric Administration through the National Sea Grant Program. This Institute-wide effort embodies three elements: an education program, a research program, and an advisory service which links us with the needs of Massachusetts, the New England region, and the nation. This program has been carried out in close cooperation with a number of industries in the area, a number of state and other agencies, and a number of other education institutions.

2. A second example is the establishment in the spring of 1972 of the Center for Policy Alternatives in the School of Engineering with Dr. J. Herbert Hollomon as its Director. The Center's objective is not merely to study policies, but to explore alternative courses for action and to identify and develop the related policy alternatives which would be required to translate possible courses of action into reality. The Center is in the process of evolution. In the short time since it was established, a total of 15 faculty members have agreed to participate in studies at the Center. Support for their activities is now being sought from foundations and the government.

This year has also been one of concern with regard to the composition of our faculty. We believe it necessary to move with appropriate speed to increase the representation of women and minorities on our faculty. We believe this not only because of the pressure from the Federal government, but primarily because of the necessity of providing role models for our students, some of whom are women and some of whom are members of minority groups. However, the number of such individuals qualified for faculty appointments in the School of Engineering is small. This is not unexpected: engineering has had few women or minority graduate students in the past. Even though the number of qualified candidates identified were few, we were able to increase the number of women and the number of black faculty in the School. However, in order to have qualified applicants in the future, we, as well as other schools, must increase the number of women and minority graduate students in our graduate schools. In an effort to do this, the School of Engineering is attempting to establish ties to the seven predominantly black engineering schools in the U.S. While our efforts are just beginning we can report that one faculty member from one of these schools will be a visiting professor next year and that several graduates from these schools will be entering our graduate school.

Another concern we have regarding our faculty relates to tenure. The size of the School's faculty has increased significantly over the last three decades. An illustration of this growth can be seen in the fact that only 38 of our 343 faculty will reach retirement age in the next decade. This must be contrasted with the fact that approximately half of the School's faculty is under age 37. Of the total faculty 58 per cent have tenure.

In the future serious problems associated with the granting of tenure must be faced. These

problems are revealed by the following extreme cases:

1. If we assume that it is good to keep our tenured faculty ratio at its present level of 58 per cent and the School at a constant size, then tenure awards made yearly must equal yearly retirements plus resignations of tenured faculty. This implies (with no resignations) that only 38 tenure slots will be available in the next decade -- about one out of each four of the present non-tenured faculty would receive tenure.

2. If instead, we assume that it is beneficial to keep the tenure rate at the present level, then with constant faculty size, we would have a faculty over 85 per cent tenured. There would be less than 50 non-tenured faculty in the School; and there would be a sizable "clump" of 100 people in the 35-45 age group preventing a substantial influx of new faculty for 20 to 30 years.

This problem has been considered at some length by the faculty Advisory Committee in the Department of Electrical Engineering. For their Department they recommend: 1) that the tenured-to-total faculty ratio be maintained in the range 50 per cent to 60 per cent; 2) that new appointments at the Assistant Professor level be 7-8 per year; 3) that the probability of a new Assistant Professor receiving tenure after seven years of service be not less than 30 per cent (otherwise low morale would ensue and/or the quality of the applicants would drop); 4) that the Department adopt a set of well-defined pre-tenure grades each lasting for a predetermined period and requiring a decision for transition to the next grade.

The work of this committee is an excellent example of the innovative thinking required in this area. We expect to discuss their recommendations, as applied to the School as a whole, further during the coming year, hopefully coupling the issues raised to the changing goals and needs of departmental programs.

During the past year, the seven departments within the School which offer undergraduate degrees were all visited by inspection teams from the Engineers Council for Professional Development. I am happy to report, that all the "designated S. B. degrees" offered in the School were reaccredited. The undesignated S. B. degrees offered in a number of departments have not been accredited in the past and accreditation was not sought for them.

I hope that this review of the School has illustrated not only the vitality of the School, but also the momentum which we are gaining in broadening our scope and in striving toward the broader goals of meaningful application of technology to society's need. I am convinced that this development is an extremely healthy one for the School of Engineering itself, and I am also convinced that through the increased interactions with the other schools at M. I. T. this development will make the Institute stronger.

In the sections which follow, the eight departments and two centers of the School of Engineering report on their activities.

ALFRED H. KEIL

## Department of Aeronautics and Astronautics

This year was characterized by an expansion of research activity in several areas, in particular, flight transportation, energy conversion and noise, generation and abatement reflecting the growing interest on the part of government agencies in societally oriented problems. The traditional disciplines of structures, fluid mechanics and instrumentation maintained their past level of support without the expected decrease in funding. In the face of this growing activity in the high technology areas of aerospace, and despite the fact that departmental graduates had little trouble in finding suitable employment in industry if they

so desired it, the Department faced a continuing drop in undergraduate enrollment to a total of 61 students compared to the previously normal average of about 150. However, end-of-term course selections indicate that 18 sophomores will enroll next fall, compared to 13 last year, and it is hoped, therefore, that this year represented the perigee.

The Department fully participated in the Undergraduate Research Opportunities Program (U. R. O. P.) and sponsored a total of 11 undergraduate seminars primarily directed at freshmen. The diversity of topics covered in these seminars may be seen from the list of titles: Fluid Mechanics; The Laser: Who Needs It!; SST; Flight Transportation; Aeronautical Arts, Crafts, and Traditions; Wind Effects on Buildings; Controlled Thermonuclear Fusion; Airport Noise, Feedback Control; Transport Economics; Environmental Measurement and Control.

In addition, nine Independent Activity Period (I. A. P.) activities were sponsored: Flight Training and Ground School; Advanced Energy Conversion; Projects Lab; Combustion Seminar; Air Traffic Control; Numerical Analysis; Lasers in Aerospace Research; Industrial Field Trip and Seminar; and Soaring Training and Ground School.

Under the chairmanship, since February, of Professor James W. Mar, the Undergraduate Committee continued the Department's efforts to maintain technical depth in instruction while at the same time emphasizing the engineering significance of the subject material. The high level of technology characterizing aerospace activities necessitates that certain departmental requirements be established which appear unduly analytical to many students. The Department attempts to compensate for this stringency by maintaining a high degree of freedom beyond the requirements, offering systems type elective subjects, and emphasizing engineering applications.

The Department also encourages students in its project laboratories to attack projects requiring innovative solutions which often lead to hardware applications. Two of the most interesting projects this year were the building and flight testing of a surface effect vehicle by two students and the continuing design and construction of a man-powered airplane having several unique features original to the student group working on this project. This airplane will be entered in the continuing competition for man-powered flight.

This year graduate enrollment decreased to 158, down 14 per cent from the record maximum of 184 two years ago, and is consistent with current trends. Student interest remains high in all of the divisions but with an increasing awareness of the possibilities presented by interdisciplinary programs such as flight transportation, biomedical engineering, instrumentation, energy conversion, and operations research. Approximately one-half the graduate students are candidates for the S. M. degree while 6 per cent seek the Engineer degree. Although the latter number is small, a proportional tripling has occurred within a two-year period. A special faculty committee chaired by Professor H. Philip Whitaker has provided the guidance for the rather broad program demanded by the Engineer degree.

Doctoral candidacy involved about 44 per cent of the student group. Professor Wallace E. Vander Velde this year oversaw the examination procedures for entrance into the program, the later general examinations, and thesis acceptance. Seven new students qualified for candidacy in the past year out of a group of 12. A lessening interest in the Ph.D. or Sc. D. as the ultimate degree is evident from the annual number of participants in the qualifying examination in each of the last several years: 39, 25, and 12.

Despite the frequent concern about employment opportunities, all of the Department's graduates have found positions. Similarly, research support within the Department has proven adequate to meet the needs of our graduate students virtually all of whom require financial assistance of some type. Research assistantships were made available to 63 per

cent of the students. An additional 25 per cent of the students received fellowship support from either the Institute or external sponsors.

Applications for admissions have fallen off in number, but with a proportionate increase in quality. Approximately three-fourths of the applicants for admission in September, 1972, were deemed admissible. The Department has been notified by 65 per cent of those admitted that they intend to register. The combined improvement in both admissions and acceptances suggests a decrease of less than 10 per cent in next year's graduate student population.

The Interdepartmental Doctoral Program in Instrumentation, under Professor Walter Wrigley's chairmanship, continues with satisfactory vigor. A total of 24 students participated in various phases of the program, an increase of five students over the 1970-71 academic year.

The Division of Mechanics and Physics of Fluids operated short-handed this year with three of its faculty on leave. Consequently, the development of a single, unified one-year graduate subject and the revision of the present series of graduate subjects was postponed until next year. In the area of research, the Fluid Dynamics Research Laboratory directed efforts towards an understanding of the interaction of ice crystals with gas and vapor molecules and on the growth of homogeneous and heterogeneous nuclei in the submicron range. This is of particular interest in determining upper atmosphere effects of high flying aircraft. Studies of interaction of inert gases with metal surfaces at moderate energies have been completed. Sputtering experiments were performed to serve as the basis for diagnostic devices in space vehicles and to gain a better understanding of surface charge exchange mechanisms. In the Aerophysics Laboratory, research continued on the effect of heat shield materials on reentry blackout of communications, on rotating bodies and wake flows using the magnetic balance system, and on an analytical study to determine the optimum configuration for the minimization of radiant energy transfer from the shock layer to a body surface and an experimental investigation of surface oxidation. Studies were also conducted on the aerodynamics of variously shaped high-speed bodies and on a ram winged vehicle which has possible application to high speed ground transportation. A laser doppler velocimeter was used to measure velocity profiles in vortex rings. Research was also continued on the generation, instability and decay of aircraft wakes, on the aerodynamics of blade vortex interaction and radiated noise, and together with the Department of Mechanical Engineering and the Flight Transportation Laboratory, on V/STOL noise propagation and minimization in urban areas. These studies were greatly helped by the completion of the low-speed tunnel designed for acoustical measurements, where tests have already been run on helicopter rotors in forward flight and on blown flaps and deflected jets.

The Instrumentation, Guidance, and Control Division, with the largest group of graduate students in the Department, has reorganized its curriculum to include more undergraduate subjects as a follow-up to the very successful freshman seminars organized by this division. Research support to the laboratories associated with this division, the Charles Stark Draper Laboratory, the Measurement Systems Laboratory, and Man-Vehicle and Laser Systems Laboratories, remains at a sound level. Work in the Measurement Systems Laboratory covered both space and aeronautical programs, including research leading to the application of new technology digital electronics to flight control systems, the application of control theory to aeroelastic problems involving ride quality and flutter, the study of wake turbulence hazards during high frequency operation at airports handling jumbo jets, and research on the skill degradation of private and commercial pilots. Space research included study of the geodetic effects of the atmosphere on the problem of satellite altimetry data reduction, the use of a gradiometer in inertial system error study, the application of guidance theory to problems relative to interplanetary flight, including the nine planets in the solar system, a program on an optimum image coding and retrieval for three-dimensional

photography, and finally the development of a dynamic error analysis program. The scope of research in the Man-Vehicle Laboratory has continued to concentrate on spatial orientation and its associated aerospace and medical problems. It includes studies of human dynamic space orientation, biophysical characteristics of the vestibular system, posture control and vestibular stimulation, pilot warning indicators, and neurophysiological experiments in eye movements. The laboratory also participated in the pilot proficiency program in the Measurement Systems Laboratory, eye stretching measurement with the Laser Systems Laboratory, the traffic situation display program with the Flight Transportation Laboratory and the study of research on motion in tall buildings with the Department of Civil Engineering. The Laser Systems Laboratory has been successful in laser frequency stabilization techniques of extremely high accuracy and are currently studying molecular beam techniques for achieving high resolution optical spectra of materials. A new type of holographic interferometer has been investigated for application in sensitive displacement detection. A technique has been developed to enable an observer to view several planes within a thick sample simultaneously with a scanning optical microscope. Laser doppler velocimeters have been developed for both low-speed and high-speed flow in cooperation with the Aerophysics Laboratory. A highly successful two-week summer program, Lasers and Optics for Applications, was conducted by Professor Shaoul Ezekiel last year and will be repeated this summer.

The Division of Energy Conversion and Propulsion is responsible for teaching and research in a broad range of subjects and has been active in problems of energy conversion both for aircraft propulsion and for stationary power generation. In the latter area research has been conducted in both MHD and fusion power. In aircraft propulsion, emphasis is placed on problems of noise generation and on optimizing gas turbine overall efficiencies. The Division's research is carried on in the Space Propulsion, Gas Turbine, and Plasma Physics Laboratories. In the Space Propulsion Laboratory a fundamental study into the determination of the feasibility of electrogasdynamic generators using mercury cesium vapors has been continued, as well as work on pulsed plasma accelerators and liquid colloid nuclear reactors. Research on combustion in heterogeneous systems applied to rocket combustion has resulted in a new understanding of the combustion process. In the Gas Turbine Laboratory work has continued on turbine cooling, on transonic compressor research, on holographic flow visualization, on a numerical analysis of transonic three-dimensional flow, and on acoustically induced flow instability in ducts and over a flexible boundary. The Laboratory for Plasma Physics continued research activities on the stability properties of nonuniform plasmas, the effects of cylindrical geometry on drift modes and the interaction of mildly relativistic beams with target plasmas.

The Division of Structures, Materials, and Aeroelasticity sponsored three special seminars in structural mechanics during the year and a symposium on research and structural topics for the Industrial Liaison Office. The research of this division, conducted primarily in the Aeroelastic and Structures Research Laboratory, placed heavy emphasis on methods of analysis for advanced filamentary composite material and on improving the understanding of failure mechanisms in such materials. The development of a special finite element method of structural analysis continued as an important and fruitful area of research activity, leading to a demonstration of the superiority of the finite element technique for determining the elastic stress intensity factor for fracture mechanics. Significant progress was made in developing methods of analysis and concepts for the containment and control of fragments of burst rotors of jet engines and on methods of analysis for structures such as nuclear power plant steam generator containment vessels and other structures subjected to intense transient loads. Nonlinear and parametric vibrations are being explored both analytically and experimentally, and recent progress has been made in the theoretical analysis of large amplitude vibrations of helicopter rotors.

The Aeronautical and Astronautical Systems Division has added three new subjects:

Airline Management and Marketing, The Regulatory Aspects of Transportation, and Transportation Economics, indicating the broadening of this division of instruction to include a multidisciplinary education in Flight Transportation. A graduate project was also conducted on concepts for the space disposal of nuclear wastes, culminating in a public seminar given by the students involved. Research associated with this division was conducted primarily in the Flight Transportation Laboratory and in the VTOL Technology Laboratory. There has been a rapid growth in the activities of both these laboratories during this year, reflecting the greatly increased research spending created by the Airways-Airport Trust Fund and the growing interest in VTOL noise problems. The Flight Transportation Laboratory organized a successful workshop on short-haul air transportation, attended by industry and academia from the United States, Canada, and United Kingdom, culminating in a report which attracted considerable attention. Primary research in the laboratory is on the development of air traffic control systems, on air transportation systems optimization, on the economics of noise reduction in VTOL aircraft, and on air freight data collection. Current research projects of the VTOL Technology Laboratory include theoretical and experimental studies of helicopter rotor blade and tip vortex interaction, the aerodynamics of wing tip flow, the development of a gust generator to simulate atmospheric turbulence in the wind tunnel, unsteady flow visualization using a helium bubble generator, and theoretical studies of terminal landing problems of jet VTOL aircraft on small ships. In addition, the Wright Brothers Tunnel, a primary facility of this laboratory, has also conducted work on the response of buildings to natural winds, on wind loads on a multi-mirrored telescope, on ground winds around buildings, and for various special programs and student research projects.

RENE H. MILLER

## Department of Chemical Engineering

The past year should prove to be an historic year for the Department as it was the year in which the Institute, upon recommendation of the Department's Visiting Committee, formally approved plans for a new chemical engineering building and a program to expand and strengthen the activities of the Department. It was a year of extraordinary effort by the Department's faculty, students, and alumni, which saw a continued growth in the volume of sponsored research (up 65 per cent since FY 1969) by the Department, an evolutionary change in the Department's educational program, and continued increase in student enrollment (20 per cent since the 1968-69 academic year).

During the past year plans were completed for a new chemical engineering building and an active campaign was begun to raise the necessary capital funds. This new facility will provide approximately 105,000 gross square feet of space at a cost of $12.2 million. It will permit consolidation of the Department's activities which are now at seven separate locations and will provide the basis for the revitalization of the Department as it moves into a period of substantial change and growth.

A group of internationally known leaders in the petroleum, chemicals, and allied products industries has joined together to assist the Institute in its solicitation effort for the necessary funds. Many of the members of this National Sponsoring Committee are graduates of the Department. Its Chairman is J. Kenneth Jamieson, Chairman of the Standard Oil Company (New Jersey). Professor Warren K. Lewis is Honorary Chairman.

Faith in the future of chemical engineering and confidence in the Department's role of innovation and leadership in the profession is demonstrated by the support of individuals and industry in the Institute's capital drive for this project. Because of budget stringencies, Federal funds are no longer available for such capital programs as this. Consequently, all of the money for the new building must be obtained from private sources, and the response to date is extremely encouraging.

Scheduled for completion in 1975, the new building will occupy the space to the east of the Whitaker Building and north of the East Campus dormitories. This location is convenient to departments with related disciplines such as Nutrition and Food Sciences, Chemistry, Earth Sciences, and Biology. I. M. Pei, the architect for the new building, is internationally known; he also designed the Green and Dreyfus Buildings which are near the site of the new chemical engineering building.

Work continued during the past year to implement recommendations resulting from the Chemical Engineering Curriculum Review conference of faculty and students held at Endicott House during the summer of 1970. Changes in subject, content, and method of presentation have proceeded in an evolutionary fashion. Professor Gary J. Powers is developing a new subject, Principles of Process Discovery, to introduce freshmen to chemical engineering. The subject will seek to convey the excitement of inventing new processes and applying the student's basic knowledge of chemistry and physics to synthesize new solutions to problems. Professor Powers received an enthusiastic response when he presented the material to a small group of freshmen as a seminar this past fall.

A major trend in undergraduate education has been increased involvement of students in research activities of the Department through the Undergraduate Research Opportunities Program. Twenty-five students were involved in intensive projects, mostly in cooperation with faculty and graduate students, on problems ranging from enzyme engineering to computer-aided design. Arrangements were made for about a dozen students to continue on these projects during the summer.

In the January Independent Activities Period, departmental activities were of three general varieties: short subjects, lecture series, and individual research projects. Topics covered in the short subjects included: Polymers, Multicomponent Distillation, Thermodynamic Equilibrium and Stability, and Digital Computation. Specialized instruction of a more applied nature dealt with Instrumentation, Machine Shop Practice, and Oral Technical Communication. A lecture series on Chemical Engineering in Biology and Medicine which involved presentations by doctoral students on their thesis work was highly successful.

Departmental research activities continued over a broad front during the past year. Many of the applications of technology to the problems of current interest to society are in areas where the chemical engineer must play an important role. Examples include biomedical engineering, pollution control, and production of clean energy. The increased availability of funds for research in these areas combined with student interest in working on these problems has led to a sustained growth in the volume of sponsored research in the Department over the past three years.

Professors Hoyt C. Hottel and Jack B. Howard completed an intensive study of problems associated with meeting our national energy requirements and the results were presented in a book New Energy Technology -- Some Facts and Assessments published by the M. I. T. Press. The book urges a vigorous research program to solve problems associated with generation, transmission, and utilization of energy in ways that protect the environment. One outgrowth of their study has been the initiation of an extensive research program on coal gasification.

In the biomedical field, Professors Kenneth A. Smith and Clark K. Colton have continued their studies dealing with mass transfer in biologically related systems. Examples include transport of oxygen through hemoglobin solutions and diffusion of oxygen through whole blood. They are also conducting research in collaboration with Dr. Robert S. Lees, Director of the Clinical Research Center, related to the genesis of atherosclerosis.

In research directed by Professor Edward W. Merrill and Dr. Leighton H. Peebles, the

past year has seen the completion of the first stages of work on two new biomaterials synthetic articular cartilage and "pure" silicone, as well as further advances in heparin-surfaced polymers for use in direct contact with blood.

The Department embarked upon a major interdisciplinary research program in the field of enzyme engineering under the sponsorship of the Research Applied to National Needs (RANN) program of the National Science Foundation and carried out jointly with the Departments of Chemistry and Nutrition and Food Science. Departmental faculty involved were Professors Raymond F. Baddour, Clark K. Colton, Geoffrey Margolis, and Herman P. Meissner. The overall scope of the research includes enzyme production, separation and purification of enzymes, enzyme kinetics, immobilization of enzymes on solid supports, and reactor and process design of biochemical reactors.

Problems in fuel utilization and combustion, as well as the incineration of solid wastes, are being studied in the Department's Fuels Research Laboratory under the direction of Professors Hottel, Glenn C. Williams, Adel F. Sarofim, and Howard.

Professor Charles N. Satterfield has continued his active research program in the field of catalysis, applied kinetics, reactor technology, and industrial chemistry. Doctoral thesis investigations have studied the performance of trickle-bed reactors, the diffusion and counter-diffusion of organic liquids with Professor Colton, and hydrodesulfurization and hydrodenitrogenation with Professor Michael Modell.

Professors Lawrence B. Evans, James H. Porter, and Gary J. Powers have expanded and initiated research in the area of chemical engineering systems. New research projects have been initiated related to control of chemical processes, sensor-based computing systems, computer-aided process synthesis and design, chemical reaction path synthesis, and systematic techniques for analysis of process safety and reliability.

The projects briefly cited here are only examples of extensive research underway in the Department, which ranges from desalination to enzyme technology and from gas absorption to process control.

RAYMOND F. BADDOUR

## Department of Civil Engineering

During this year the Department has made substantial progress in broadening its educational and research efforts to incorporate the physical and social environmental impacts associated with constructed facilities. The framework within which this evolution is taking place is summarized in this report.

The civil engineer is responsible for providing society with its constructed facilities; opportunities for him to exercise imaginative leadership in this role have never been greater than at this moment of shifting national goals.

Population growth and rising standards of living have produced a close coupling between the economies and environmental qualities of the industrialized countries. On one hand, our increasing numbers and rising expectations create a rapidly escalating demand for energy, transportation, and other public services; for housing and for a variety of commercial and industrial facilities. On the other hand, we are beginning to realize that the continued satisfaction of these needs and desires in a manner which is dictated by purely economic criteria and using conventional technology is counter both to the realization of short range quality-of-life goals and in the long range to the very survival of life. Achieving the necessary accommodation between man and his social and physical environments presents

a new frontier for the civil engineer and a new challenge for his system of professional education.

In the past, with economic expansion as an overriding national goal and with economic efficiency as the principal criterion for action, we looked primarily to new technology for the solution of our development problems. Indeed M.I.T. and this Department acquired their leadership positions largely through significant contributions to physical understanding, to improvements in engineering analysis, and to the creation of new devices. Continuation of such contributions is necessary in order to alleviate environmental stress and to reach the desired accommodation with nature. However, as national goals shift toward limited economic growth with an emphasis on a high quality of life for all, technological leadership is no longer sufficient to insure, for civil engineers, other than the technologist's role in the provision of constructed facilities. Believing that engineers bring a vital perspective to the planning process, we must broaden the scope of our education to deal with the decisions of what gets built in addition to how it occurs.

For the short range we must learn to consider the effect of our construction upon the quality of life as determined by such hard-to-quantify social factors as public health, safety and convenience; community integrity; recreational opportunity; sense perception and many others. Recognizing that these environmental impacts will act differentially upon various segments of society we must learn to generate technically and economically acceptable alternative solutions to a given problem each having a different impact matrix and then to involve the affected community in the process of choice. As these constraints upon our actions multiply, the process of satisfying a perceived facility need will become ever more complex. This, in the face of increasing facility needs, demands that we give greater attention to the organizational and managerial aspects of our fundamental role.

For the long range we must also recognize that our planet has finite environmental resources, that its life forms have evolved in dependence upon the natural environment, and that man has attained the ability to make significant changes in this environment. We must now learn how to assess the physical effects of our engineering works upon natural systems in order that we may seek alternatives which minimize environmental impacts and where necessary provide a rational basis for regulatory legislation.

To meet the future needs just outlined, our educational programs must provide more variety than in the past when emphasis was almost solely on analysis and design. At the undergraduate level we need to spend time addressing the "What?" and "Why?" questions of constructed facilities in addition to those of "Where?" and "How?" This must be done early and continuously to provide motivation and to generate and maintain perspective. Before asking the student to choose a field for specialization in depth he should be introduced, not only to analysis and design, but also to the tasks which precede and follow these in the process of realizing constructed facilities, namely: recognition of issues, assessment of need, formulation of objectives and constraints, search for alternative solutions, forecast of impacts, action recommendations, financing, construction and management. We have taken a first step in this direction with our new undergraduate curriculum which was described in detail in the past two annual reports of the President.

At the graduate level we need to provide first for the student who intends to practice civil engineering. The S.M. program has served this need in the past. For the increasing numbers who want additional advanced education without the research commitment of the doctorate, we have provided an "enhanced" civil engineer degree program with major options in either Design and Construction or in Planning and Public Policy. The doctorate will continue to serve those interested in teaching and/or research, however, we expect these students to decrease in number. To more fully serve the profession, we must find means of financial support and of recognition of achievement sufficient to induce the practicing

engineer to interrupt his career for periods of intensive course work.

## The Undergraduate Program

Our undergraduate enrollment continues to rise and now stands at 116 students, the highest it has been in 13 years. We are among the few departments of the School of Engineering who are experiencing an enrollment growth trend and this must be due in large part to the increasing public concern with civil sector problems. There is evidence of another causative factor however, which is the breadth and largely preprofessional character of our new undergraduate program. This evidence consists of: 1) a decreasing demand for the B.S. degree without specification within this Department; and 2) increasing numbers of our students who intend to go on to graduate work in law, management, public administration, etc.

The Class of 1972 was the first for which the new curriculum was available (although not compulsory). It is interesting to note that 19 students chose to complete the old curriculum and 23 the new. Of the latter, six chose primaries in the applied mechanics areas, while 17 elected the broader areas involving planning and management.

During the year a new primary field of Environmental Engineering was added bringing the current number of approved primary fields to eight.

## The Graduate Programs

The number and quality of U.S. and Canadian applicants for admission to the Department as regular graduate students has remained essentially constant over the last three years as has the percentage yield of those admitted. The total number of regular graduate students is being voluntarily held to a level (about 192) below the Department's quota of 200 in accordance with a budgetary decrease in faculty size. We have also decreased the percentage of regular foreign students to 27 per cent from a high of 37 per cent three years ago.

On the other hand, we have mounted an aggressive campaign in the local professional community to attract special graduate students since these create no thesis supervision load. This effort has increased our enrollment of special graduate students from 15 to 30 over the last year.

Under the leadership of Professor Charles C. Ladd, the Department Committee on Graduate Students upgraded the requirements for the degree of Civil Engineer, effective September, 1972, in order to make it a more significant degree for students wanting graduate study in greater depth and breadth than is required for the S.M. degree but who do not want the research concentration which is characteristic of doctoral programs. The two-year program includes a primary area of concentration equivalent in depth to that followed by doctoral students and requirements for breadth both within and outside of traditional civil engineering disciplines. Two options are available: Design and Construction, which encompasses those areas generally founded upon the physical sciences; and Planning and Public Policy, which draws heavily upon systems analysis, economics, and the social sciences.

This Committee also clarified the Departmental requirements for the S.M. degree with and without specification introducing the requirement that all S.M. candidates must now file an approved program of study.

An S.M. program in the management of capital facilities projects (Projects Management Program) was developed and approved by the faculty during the year and the first students will enter the program in September, 1972. The goal of this academic program is to provide an understanding of the organization and operation of the construction industry, the role of technology in the industry, and the disciplines used in the management of industry operations. The scope of the program will encompass all aspects of the total development process and

will not be confined to the construction phase. The program includes a core sequence of five subjects which focus on the organization and operation of the construction industry, the anatomy of the project realization process, and essential project management disciplines which bear upon these processes. Three of these subjects will be offered jointly by faculty from the Departments of Civil Engineering and Architecture and the Sloan School of Management. In line with his own special interest, each student will select a supplementary set of electives from other existing subjects at M. I. T. or Harvard University which will provide some depth in one or two project management disciplines.

## Research

The Department's research volume continues to grow and for FY 1972 was approximately $2.7 million. The reasons for the continued growth in the face of a shrinking faculty are threefold: 1) inflation, 2) additional research assistantships to compensate for the declining Federal fellowship support, and 3) increasing use of full-time D. S. R. personnel to provide the day-to-day coordination required by the large scale, group-type research projects and studies which we are encouraging and which increasingly include the gathering of field data.

Among the newer research efforts are several of particular interest:

The sea environment in Massachusetts Bay and adjacent waters is a major interdisciplinary project being carried out under the M. I. T. Sea Grant Program. It is concerned with many aspects of coastal zone problems, including water movement, water quality, thermal discharges, and the environmental effects of sand and gravel dredging. The project is conducted in cooperation with the Departments of Meteorology and Earth and Planetary Sciences under the joint leadership of Professors Arthur T. Ippen and Erik L. Mollö-Christensen. Also cooperating with this project are a group of biologists from the New England Aquarium and a number of industrial, state, and Federal agencies. Direct project supervision has been provided by Professor John D. Ditmars. Of significance is that this is the first research program of the Water Resources Division in which students and faculty are actively involved in all phases of the instrumentation, planning, and collection of field data.

Professor Robert Van D. Whitman is directing a National Science Foundation (NSF) sponsored effort to develop regulations, suitable for adoption by Federal agencies supporting new construction, which will provide an optimum level of earthquake protection for new multi-story housing in Eastern metropolitan areas.

Professor Frederick J. McGarry, with NSF support, is supervising the development of a computer model of the tunneling-excavation process which will be used: 1) to conduct sensitivity analyses to identify needed technology; 2) to make cost-benefit analyses of proposed technological innovations; 3) to provide a rational means for tunnel cost estimation incorporating the use of probabilistic methods where appropriate; and 4) to permit optimization of the total tunneling system according to selected objectives.

Professors Marvin L. Manheim, Wayne M. Pecknold and James T. Kneafsey are working with the Federal Highway Administration to develop new environmental procedural guidelines for highway planning and design. This activity is part of a larger project concerned with transportation and community values that involves development of a procedural guide for community values in highway location and design to be used by state highway departments throughout the country. We are working with the California State Highway Department to apply the principles developed in the guide to ongoing projects.

A number of investigations dealing with environmental impacts of energy generation are being conducted: Professor Donald R. F. Harleman, in the analytical and physical modeling of heated discharges; Professor David H. Marks, in the siting and management aspects of

power production; Professor Michael S. Baram, in the area of legal constraints by regulatory bodies; and Professor Stephen F. Moore, in the environmental effects of offshore tanker installations. Although most of these studies were originally undertaken independently, during the past year there has been a growth in the interaction and communication between faculty and research students within this Department and with the Energy Systems group under Professor David C. White of the Department of Electrical Engineering. A focal point for the broad range of interests in the energy problem has been provided by the initiation of research concerned with the proposed Atlantic offshore nuclear generating station for the Public Service Electric and Gas Company of New Jersey. Floating nuclear units are to be partially enclosed by a large breakwater at a site 2 to 3 miles offshore. In addition to thermal discharge studies, Professor Chiang C. Mei and Ole S. Madsen are investigating storm wave generation, breakwater stability, and internal waves and mooring problems.

PETER S. EAGLESON

## Department of Electrical Engineering

Enrollment in the Department of Electrical Engineering, both graduate and undergraduate, continues to be high, and total enrollment for the coming year will probably increase. This is in marked contrast to the national trend in engineering enrollment which has been sharply downward. Nevertheless, there are serious problems that must be faced if we are to continue to retain our present position of national leadership. Most importantly, we must find a usable definition of the proper domain of electrical engineering, and then determine the proper criteria for choosing those problem areas that in some sense maximize the "product" of: 1) social importance; 2) technical interest; 3) long-range benefit to the Department; and 4) interest to the Department's faculty and students.

There are many important technical areas of electrical engineering that are not explicitly represented in either our teaching or research. Even with a faculty as large as ours, it is not possible to cover everything "of importance." Thus we must choose those areas where we can make the greatest impact, and that we believe have the greatest long-term importance.

The recent recognition that M.I.T. can no longer grow indefinitely, and thus that our Department will have to adjust to a stable (or shrinking size) presents us with problems of developing a faculty promotion and career development policy that will be fair to the individuals and that will permit the Department to keep its intellectual vigor.

With these problems in mind, a departmental Advisory Committee was established, consisting of 21 members, broadly representative of the Department's faculty in age, rank, and technical interests. Its charter was to forecast and plan for the long-range development of the Department. Subcommittees have been established to study faculty development, research policy, undergraduate education, and graduate education.

A number of basic assumptions or observations have been made that indicate the forces for change that are acting on us:

1. The computer in all its forms, from "mini" to large time-shared systems, has already assumed a central position in electrical engineering.

2. The problems we must deal with will grow in complexity and it will be necessary to develop new theories and intellectual tools to handle them.

3. The "primitive" elements of electrical circuits have evolved from R, L, C, and

transistors to complex integrated circuits and even small computers.

4. The question of training students to deal with problems of organization and structure ("software") without sacrificing their competence in hardware and applied physics sharpens the issue of options or of several undergraduate curricula versus a common core curriculum.

5. The military and space activities of the nation have been the principal forces for the development of high-technology engineering during the past 30 years. If, and as, the focus swings toward civilian needs, the legitimate needs for high-technology systems present a major theoretical and even philosophical challenge to which we must respond.

6. The internal management of a zero-growth department is an issue of major importance if the above questions are to be dealt with effectively. Place must be made for new, young faculty members in order to bring in fresh ideas and viewpoints. This requires a careful management of our appointments, promotions, and granting of tenure.

The Advisory Committee, through its subcommittees, has spent considerable time and effort in formulating the questions it will address and in preliminary answers to some of them. They have made preliminary proposals for a more formal and explicit framework for promotion of non-tenured faculty with a recommendation that the overall probability of achieving tenure be held to about 0.3.

The question of a research policy for the Department proved to be difficult. On the one hand, there is a tradition of academic research within which a professor can engage in any legitimate activity for which he can find support and interested students. On the other hand, someone must be ready to say that "this" area of research is more important to the Department than "that," and there must be some coherent set of ideas that permits such decisions to be made. No real progress has been made here except to begin the definition of the issues.

An interim report of the Advisory Committee has been drafted and will form the basis for further discussions during 1972-73.

LOUIS D. SMULLIN

## Department of Mechanical Engineering

Compared with the past few years the mood within the Department was quite different for two reasons. First, there was a virtual absence of student activism, although we retain as a permanent feature the close involvement of and consultation with students concerning our undergraduate and graduate programs. Second, the stringencies associated with successive budget cuts and with the massive efforts to obtain funding for new directions of effort have made the past year a strenuous one for the entire community of individuals within the Department.

Our total undergraduate enrollment has remained steady within the expected statistical fluctuations from year to year. The number of students in Course II-A, the unspecified program for the degree of Bachelor of Science, appears to have reached a steady state with about 15 per cent of the Department's sophomores enrolled and a gradual increase to 30 per cent by the senior year. The caliber of students in this program continues high; five of the 12 seniors in the Honors Course were from Course II-A. During the visit of the Accreditation Committee of the Engineers Council for Professional Development (ECPD) it was established that the program is not accredited because it is loosely structured. Review of individual records of an overwhelming number of students in Course II-A did, however,

indicate that the ECPD requirements were met.

The graduate enrollment as of September, 1971, was 219 which is about the same as in the previous year. We are finding it increasingly difficult to support graduate students due to the drastic reduction in Federal fellowships and to the general inflation which has reduced the value of the research dollar. There has been a modest but distinct trend toward employing postdoctoral research associates rather than predoctoral research assistants on research grants and contracts as a means of doing more for less. However, this gives us pause inasmuch as we conceive our research programs as being an important factor of graduate education.

While the employment opportunities for engineers throughout the country remain gloomy, our graduates seem not to have suffered too badly. The number of offers received may be less and the salaries not as high but, nevertheless, our graduates do get jobs and good ones.

During the year, the faculty moved to restructure the cooperative program, Course II-B, with greater emphasis on jobs during the summer as the means of gaining industrial experience. As an exploratory step toward this end many faculty members, using their contacts in industry, helped obtain summer jobs for students during the summer of 1972.

It remains one of our most difficult and frustrating tasks to inform freshmen--and by inference the entire lay public--of what mechanical engineering as a profession is really all about and of the multitude of exciting things that mechanical engineers do. During the past year an ad hoc committee made continuous efforts to reach the freshmen so that those whose interests really were in mechanical engineering would come to realize that fact.

At the meeting of the Visiting Committee of the Department held in November, 1971, the principal theme was our broad program in biomedical engineering. This program now accounts for approximately 20 per cent of the research efforts of our faculty and graduate students and an approximately equal fraction of our total research funding. It is notable that approximately 14 individuals whose primary appointments are at hospitals and medical schools in the Boston area have appointments in this Department as Lecturers or Research Affiliates in recognition of teaching and research collaboration with faculty members of the Department.

A massive effort was made toward identifying and evaluating present and future candidates for faculty and other professional positions from among women and members of minority groups as part of our Affirmative Action program. In addition, the Department was active in trying to find ways by which women could move into more responsible positions and to discover qualified candidates from minority groups for such positions as technicians and secretaries.

The undergraduate honorary society, Pi Tau Sigma, has improved and expanded its evaluation of subjects of instruction and of teaching effectiveness. This now extends to all subjects, undergraduate and graduate, and to all teaching members of the staff. These efforts have been highly beneficial for the students, for the faculty and for the administration of the Department.

Recommendations by the Undergraduate Committee for restructuring the management of the undergraduate core curriculum were approved by the faculty. The core program will be divided into three series of subjects with a professor in charge of each series. This faculty member will also be co-professor-in-charge of each subject in his series. The series professors will be responsible for the coherence and coordination of the several subjects in their respective series. As part of this plan, there has been established an Undergraduate Executive Committee which consists of the department head, the Chairman of the

Undergraduate Committee, and the three series professors. This Undergraduate Executive Committee is responsible for the overall coordination of the core curriculum and also makes recommendations to the department head as to the professors in charge of core subjects and teaching assignments for these subjects. We hope and expect that this new administrative plan will make our present undergraduate curriculum more effective and also will be an important factor in the projected study and restructuring of the core curriculum.

The Department is one of the more active at M. I. T. in those informal categories of instruction that are exemplified by the U. R. O. P. program and by undergraduate and policy seminars. At the request of the Committee on Educational Policy an extensive survey of what has been designated as "seminar-research" type activities was conducted. These activities are characterized by teaching and learning experiences in small groups, by the fact that the subject matter is not fixed but varies with each group, and by the fact that the students participate in defining the problem as against exercising to solve an already stated problem. The "seminar-research" activities of the Department approach one-eighth of the total unit requirements for the Bachelor's degree, but are about one-third of the departmental requirements for the degree. In addition, there are many additional units of unrestricted electives in the departmental program that could be of the "seminar-research" type.

Despite the unfavorable economic climate and the reduction of Federal research funding the Department has been extraordinarily successful in securing research grants and contracts. In the period since 1967-68 at which time Federal research funds were at their zenith, the dollar volume of research within the Department has increased in each year. In 1971-72 the dollar volume was $2,772,000 compared with $1,849,000 in 1968-69; this corresponds to an increase of 50 per cent in three years. This remarkable accomplishment has been effected through the loyal and hard-working efforts of individual faculty members and is all the more notable because much of the funding is in new areas in which the faculty had to establish their competence.

## Research

Several areas of research effort are especially interesting.

Our activities in acoustics and environmental noise control are expanding rapidly and include projects involving sound transmission in buildings through plasterboard walls, noise propagation from aircraft into downtown and residential areas, and speech privacy in open-plan offices; efforts are being made toward the earthquake isolation of structures by foundation pads of ductile metals; an extensive program in biomechanics and human reproductive physiology is under way; methods for improving the life of tungsten carbide tools are under investigation; the role of fabric structure on flame propagation in clothing is being studied; in a collaborative effort with members of the Department of Electrical Engineering, the broad program of application of superconductors to electrical generating machinery is successfully moving ahead and offers great promise; improvements in the preservation of human blood by freezing are likely outcomes of research done collaboratively with the Harvard Medical School; extensive studies are being made of the mechanisms of formations of oxides of nitrogen in the burning of various fuels, among them the combustion of gasoline in automotive engines; a wavelength-tunable laser system under development appears to be most promising for spectroscopy in the infrared; and the broad range of efforts toward assisting those handicapped by blindness or loss of limbs continues and plans are being developed for the establishment of a rehabilitation center in which the faculty would collaborate with the Children's Hospital.

ASCHER H. SHAPIRO

# Department of Metallurgy and Materials Science

An ad hoc committee of faculty and students, under the chairmanship of Professor Bernhardt J. Wuensch, put the finishing touches on the new undergraduate curriculum which will be instituted in the first term of the 1972-73 academic year. The curriculum features three laboratory subjects which are not illustrative of any particular lecture subject, but are designed to acquaint the student with the apparatus used by practicing materials scientists. There are three core sequences of lecture subjects, in mechanical behavior of materials, in thermodynamics, and in structure and structural change. Upperclass professional subjects include physical and chemical metallurgy, non-metallic materials, and materials processing. A permanent curriculum committee will be established having, among its other duties, the responsibility of monitoring the adequacy of the curriculum; it will then be ready to respond to student suggestions.

Enrollments in service subjects remained high, with 231 students registered in the fall term and 144 in the spring term for 3.091, Introduction to Solid-State Chemistry; 3.141, Science of Materials, attracted 53 students in the fall term and 58 in the spring term; 3.19, Techniques of Metal Sculpture, was, as usual, oversubscribed with 53 students in the fall term and 53 in the spring term. To ease the pressure on enrollments, the subject will also be offered during the summer term.

It is perhaps appropriate to mention that, in response to the suggestions of the Committee on Educational Policy (C.E.P.) regarding the establishment of an undergraduate division with a deeper involvement for all students in undergraduate research, the Department has surveyed its present activities. The Undergraduate Research Opportunities Program, 3.U.R., enrolled a total of 16 students during the year. There was one undergraduate seminar with nine students in each term. The undergraduate thesis, restricted to students in Metallurgy, attracted nine students per term. And, during the Independent Activities Period in January, about 170 students were involved in the various offerings of the Department.

Fifty undergraduates were enrolled in Courses III and III-A this year, a number which is cyclically lower because of the small second-year class in 1970. It appears that these unpredictable fluctuations will have to be lived with. The Cohen Award, sponsored by the local section of the AIME was won by Miss Debra Judelson. The award is given to the outstanding junior of the year and is open to students at M.I.T., Brown University, Dartmouth College, Northeastern University, and the University of Massachusetts.

In graduate subjects of instruction, an interdepartmental sequence in polymers has been developed in conjunction with the Departments of Civil, Mechanical, and Chemical Engineering. The sequence is supervised by a committee established by Professor Donald R. Uhlmann of this Department and Professor Frederick J. McGarry of Civil Engineering.

Graduate student enrollment was slightly lower at 132 regular students and 2 special students. While research funding for the graduate school has remained at about the same or even slightly higher level for the last two or three years, there is no question that the purchasing power of the research dollar is considerably lower, and this is the main factor which accounts for the slight dropoff in graduate enrollment. There are, however, hopeful signs that new sources of funding including those dealing with applied technology, particularly materials processing, supported by the National Science Foundation and the Advanced Research Projects Agency (ARPA), together with possible support from Research Applied to National Needs (RANN) and the Environmental Protection Agency will raise the total support of the graduate school to a significant extent in the next two or three years. This is part of the general

trend towards more applied research and may cause us to give some thought to the possibility that a slightly different experience in graduate school than that which leads to the research degree of Sc. D. or Ph. D. will become a possibility in the future.

The graduate research programs of the Department are, with one or two exceptions, included in the Annual Report of the Research in Materials Science and Engineering. Hence, it is necessary only that a short summary of research highlights be given here. In what follows, there is no pretense that a careful selection of those projects which are the most significant has been made.

In the physics of solids area, theoretical work has included the development of a spin-unrestricted self-consistent-field cluster method for calculating, from first principles, the electronic structures of complex molecules and solids. Fortunately, the method requires only moderate amounts of computer time. It has been applied to free molecules, transition metal complexes in crystalline and noncrystalline environments, impurities and vacancies in crystals, disordered materials, optical and magnetic excitations in crystals, chemisorption on catalytic interfaces, and biological macro-molecules.

Experimental work has included determination of the structures of amorphous arsenic-selenium glasses. These materials are important photo-conductors and have recently been used as the basis for a series of amorphous semiconductors. Definite molecular groupings are used in the amorphous structure and the form of these groupings changes with composition.

An electron diffraction unit with an electron energy selection system in the diffracted beam has been developed for the determination of the structure of thin films and has been used to determine atomic arrangements in a series of amorphous semiconductors. The plasma losses have also been measured and these data have been related to the electronic energy levels in the film. This is regarded as an important development in the study of surface states.

Collaborative work with the Francis Bitter National Magnet Laboratory has involved the use of fields up to 220 kG to study electronic or magnetic interactions in solids by overriding them with the magnetic field. For example, magnetic breakdown of beryllium has been studied in fields up to 150 kG, Galvano-magnetic effects in graphite crystals have been investigated to 220 kG and high field, quantum-oscillatory phenomena have been investigated in extremely pure iron and cobalt whiskers.

Work has also been completed on the low-temperature aging of martensite and this has led to the development of a direct difference technique for analyzing Mossbauer spectra and a more complete understanding of the aging-tempering process.

In physical metallurgy, a new nucleation model in which the interfacial dislocations surrounding a pre-existing embryo are moved by a transformational driving stress has been developed. The stress has been identified with the free energy gradient. The growth path can then be described quantitatively through the radial growth and thickening of disc-like embryos. These processes, once initiated, undergo rapid acceleration and achieve athermal characteristics as in martensitic transformations. The model has now been checked at high magnetic fields (with the cooperation of the Francis Bitter National Magnet Laboratory) which permit the transformational driving force to be varied in a systematic way at a given reaction temperature. The fields induce significant nucleation rates at temperatures where the chemical free-energy change is too small for detectable nucleation.

There has also been experimental research concerned with the structure, thermodynamics and kinetics of crystalline and amorphous phases in multicomponent systems and the

deformation and annealing of metals and alloys. A review of the subject of stored energy of cold work in metals was completed and theoretical analyses of several kinds of materials having compositional or structural gradients were carried out. Investigation of the relaxation of amorphous selenium-tellurium alloys containing 0-35 atomic per cent tellurium, at temperatures ranging from room temperature to 318°K, has been completed. The effects of composition, temperature and time of annealing on the various properties have been explained in terms of structural changes and relaxation kinetics. This work is important with regard to amorphous semiconductor materials in general.

Compositional and structural gradients can be present in metals, ceramics, polymers and composite materials and they can have important effects on their properties. Gradient materials are now beginning to attract attention and have been studied here (in collaboration with the California Institute of Technology) in composite materials and (in collaboration with the University of California) in polymeric materials.

In the biomedical materials field, the dynamical mechanical behavior of cancellous bone has been characterized at physiological frequencies and a structural model has been developed for the static mechanical properties of this material. The structural changes which occur in the early stages of osteoarthritis have been characterized and a new model has been developed for the role of impact and abnormal motion in the development of this type of arthritis.

It has also been established that the surgical implant casting alloy, Vitallium, when hot worked, cold worked, and heat-treated has superior tensile properties to as-cast alloy; it also has superior wear and corrosion-resistant properties. In addition, it has been established that the resistance to fretting corrosion of titanium alloys, however prepared, can be appreciably increased by plating such materials, chemically or otherwise, with a thin layer of platinum or palladium, followed by a thermal treatment in air at 200 °C. A method to increase the wear-resistance of total joint replacement prostheses of titanium has now been found; it involves cladding with wrought Vitallium alloy.

In materials processing, it has been shown that splat cooling of a copper-40 per cent zirconium alloy results in an amorphous structure, evidenced by subsequent recrystallization under the electron-beam heating of the electron microscope. The interesting part is that this alloy does not contain a metalloid, which has been the case in all previously reported amorphous alloys.

The strongest carbide-dispersion-strengthened alloy, using nickel as the base metal, has been produced; furthermore, the alloy has good ductility at low temperatures. A somewhat similar result has been obtained with an iron-base beryllium-oxide strengthened alloy.

Solidification research, which has been unusually productive in recent years, has resulted in a quite new phenomenon, the casting of semi-solid alloys (rheological casting). Provided the alloys are well-agitated they may be as much as 50 per cent solid when cast. A number of new forming processes seem possible.

Eutectic compositions can be solidified with aligned "composite" structures which have potential as high-temperature materials. Recent work has shown that these results need not be restricted to binary alloys, which opens the door to an exciting prospect for many high-temperature alloys for gas-turbine compositions.

Work has been continued on the so-called forming-limit diagram, which is now in widespread use for sheet-metal stamping design and failure analysis. The imposed strain-rate has been shown to modify the strain-hardening characteristics, but in a controllable manner.

Work on reactor materials has included a study of void nucleation during neutron irradiation; such nucleation gives rise to severe swelling and poses a threat to the development of the fast-breeder reactor. The theory of this phenomenon has been developed; it is now being used in modeling programs for the fast-breeder reactor and is expected to be useful also in studies relating to fusion power.

In non-metallic materials, work has encompassed both ceramics and polymers. Some of the ceramics work has been directed to MHD generator materials such as thoria, alumina and magnesium oxide. Thermal gradient studies on mixed oxides for nuclear reactors have also proved useful in characterizing the problems associated with fission product migration in uranium or plutonium oxide matrices.

Chemical vapor deposition studies of uranium oxides, magnesium oxide, the magnesium spinels, and zirconia-yttria solutions have continued and considerable progress has been made in characterization of the important growth factors.

The deformation of amorphous and semi-crystalline polymers has been studied with the interesting result that there is a pronounced effect of various secondary recrystallization treatments. Studies of polymer crystallization under pressure have also been continued, particularly on the polyethylenes.

An associated, much-publicized, topic has been the study of crystallization, melting and viscous flow of lunar material compositions supplied by NASA.

In the corrosion laboratory, work on stress-corrosion cracking has shown conclusively that there is a critical potential below which failures do not occur in otherwise aggressive chemical media. This could be very important in preventing failures of desirable metals by suitable galvanic coupling.

An advance in electron microprobe analysis has been obtained with determination of accurate correction factors for the absorption of X-rays as they leave the sample.

THOMAS B. KING

## Department of Nuclear Engineering

The primary objectives of the Department of Nuclear Engineering are to provide advanced technical education in the fields of engineering and applied science related to nuclear technology, to contribute to advances in these fields through research, and to assist society in making use of the benefits of nuclear technology. The most far-reaching of these benefits is the production of useful energy from nuclear reactions, on which much of the Department's attention is focused.

Orders for nuclear fission power plants increased substantially in 1971 and early 1972 so that approximately 50 per cent of new U.S. baseload capacity additions of thermal power plants by the electric utilities were nuclear. A recent national power survey by the Federal Power Commission projects a total U.S. nuclear electric power capacity of 140,000 megawatts, which would be 28 per cent of the projected U.S. installed electric generating capacity at that time. This continued major commitment to nuclear fission energy by the utilities has taken place during a period when strong counter actions have been taken by some public groups who are questioning the environmental impact of all energy production and in particular the effectiveness of certain safety systems which are incorporated in present nuclear power plant designs. These two trends -- increasing demands for nuclear power plants and increasing attention to plant safety and other environmental concerns -- are playing a significant role in shaping the Department's programs related to the peaceful uses of nuclear fission.

The past year has also seen an increase in both governmental and industry interest in, and support of, the development of nuclear fusion as a practical source of energy for society. The Department's strong activities in this area are gradually shifting toward the application of the results of plasma-related research to the development of engineering information that will eventually be required for fusion power systems.

The Department offers graduate programs leading to the degrees of Master of Science, Nuclear Engineer, and Doctor of Science or Doctor of Philosophy. The Master's degree program provides education appropriate for graduates who are being employed in increasing number at the nuclear power plants now coming into operation. The program leading to the Nuclear Engineer degree involves about two years of graduate study and is proving especially suitable for persons employed in designing or building nuclear power plants or managing their technical operation. The programs of study leading to the Doctor's degree are aimed at providing a comprehensive knowledge of nuclear engineering, at developing competence in advanced engineering research, and at developing perspective in assessing the role of nuclear science and technology in our society. Graduates of these programs continue to find a demand for employment in a variety of activities in government, industry and universities. One trend that has become evident during the past two years is that an increasing number of graduates from all three degree levels have been offered and are accepting employment with electric utility companies to assist them in the evaluation, construction, operation and planning of nuclear power stations.

While the Department's degree programs all remain at the graduate level, a strong commitment to the provision of undergraduate educational experiences in nuclear engineering has developed. The Departmental programs in this area presently include conducting undergraduate seminars, participating in the Interdisciplinary Environmental Projects Laboratory, supervising undergraduate theses, offering three subjects for undergraduates, and offering five-year combined S.B. and S.M. degree programs with the Departments of Physics, and Civil, Chemical, Electrical, and Mechanical Engineering. In addition a series of undergraduate subjects dealing with nuclear engineering will be developed during the 1972-73 academic year as electives for students in other M.I.T. departments to assist in their preparation for careers in the energy sector of the economy. Furthermore, this year Professor Irving Kaplan has been developing a new freshman-oriented subject, Nuclear Engineering in Society, which will be offered in 1972-73. In addition to providing an introduction to nuclear technology, this subject will direct attention toward the problems that must be solved so that nuclear energy will be able to contribute to the solution of national and world energy problems.

In the area of curriculum development, Professor Sow-Hsin Chen has reorganized and modernized the subject, Nuclear Measurements Laboratory, emphasizing solid state detectors and measurements involving the M.I.T. Reactor. Under Professor Michael J. Driscoll the group design project in Nuclear Reactor Design this year involved a detailed analysis of two electric breeder concepts: a scaled-up version of the proposed Canadian Intense Neutron Generator and a fission-fusion reactor. Professors David D. Lanning and James W. Gosnell, in Nuclear Reactor Operations and Safety, treat principles of operating nuclear reactors in a safe and effective manner, including analysis of past accident experience and review of safety analysis reports, reactor technical specifications, and other Atomic Energy Commission (AEC) licensing regulations. In Radiation and Radioisotopes Engineering, Professor Gordon Lee Brownell has increased the cooperation with the School of Public Health at Harvard University which is expected to lead to an integrated series of subjects in the biological effects of ionizing radiation. Professor David J. Rose introduced a new subject, National Socio-Technological Problems and Responses, which treats the methodology for, and current results of, the assessment of energy, environmental and other socio-technological problems. Professors Norman C. Rasmussen and Michael W. Golay are preparing material for a new subject, Environmental Impact of Nuclear Power, to be offered in the

fall of 1972; included are comparisons of the types of effluents discharged from nuclear and fossil power generating plants and the benefits and risks to society from various forms of power generation.

Four special educational programs are being offered each summer for people in industry, government, and academic personnel. The subjects are Nuclear Power Reactor Safety directed by Professor Norman C. Rasmussen; Nuclear Fuel and Power Management directed by Professor Edward A. Mason in conjunction with Professors Manson Benedict and Kent F. Hansen; Physical Aspects of Nuclear Medicine directed by Professor Brownell; and Neutron and Light Scattering directed by Professors Chen and Sidney Yip. These intensive one-to three-week programs have been well attended and make important contributions to the continuing education of technical personnel already working in the nuclear field.

The M. I. T. Research Reactor, under the direction of Lincoln Clark, Jr., continues to be the Department's most productive and versatile research facility. In addition, it serves as an essential vehicle for instruction on the operation and characteristics of reactors and on the properties and uses of reactor radiation. It is also used extensively as a radiation source for research by several other M. I. T. departments and New England organizations outside of M. I. T. Engineering studies made by students in connection with the proposed redesign of the reactor provide uniquely valuable real-life engineering education. During the past year, the reactor was used in an "Environmental Analysis" laboratory subject offered by Boston University and funded under a new AEC reactor-sharing program. During this year additional design and licensing work has been carried out by Professors Lanning, Gosnell and Research Associate Edward J. Barnett and their students on a major modification of the reactor. In this new design the heavy water cooled and moderated core would be replaced by an undermoderated core cooled by light water and a heavy water reflector in which fast neutrons are thermalized to produce a significantly higher flux in the experimental positions. Final AEC licensing action is expected in the latter half of 1972; if construction approval is granted and available funding is adequate, physical modification of the reactor will be initiated.

Professor Chen and his students have been using new triple axis spectrometer at the MITR for experimental research on the structure and properties of various materials. Under the supervision of Professor Michael J. Driscoll five doctoral students have completed their research at the Reactor on the behavior of neutrons in fast reactor blankets. Professor Lanning and his students have continued their studies of the engineering of liquid helium systems and the production and use of cold neutrons at the reactor. Professor Brownell, Dr. Donald Hnatowich, and Miss Helen Connor have been engaged in a study of the production of Fluorine-18 in the Reactor and its application in nuclear medicine. Working with Professor Brownell, Dr. Hnatowich has developed a neutron activation analysis program at the MITR for the analysis of commercial, biological and environmental samples.

Professor Allan F. Henry and his students have continued the development of methods for predicting nuclear fuel depletion effects, under support of Combustion Engineering, Inc. With the support of Commonwealth Edison Company, Professors Benedict and Mason and their students are developing methods for nuclear utility system optimization for the design, purchase and management of nuclear fuel for reactors.

Under AEC sponsorship, Professors Hansen and Henry and interested students are continuing work on the development of numerical techniques useful in analyzing reactor dynamics. In other studies, Professors Benedict, Lanning, and Mason have carried out studies on fuel designs for plutonium recycle and on the value of the plutonium isotypes in recycled fuel. A growing number of students are working with Professors Lanning, Driscoll, Rasmussen, and Neil E. Todreas on problems related to both thermal and fast reactor safety.

During the past year, the Department's activities in applied plasma physics have given

increasing emphasis to the engineering requirements of complete thermonuclear fusion power systems. Professors Lawrence M. Lidsky and Ronald A. Blanken and their students have continued their work on the construction of the ALCATOR torodial fusion plasma experiment and the development of the plasma diagnostic schemes relevant to this experiment. Particularly pertinent was the successful completion of several laser scattering experiments aimed at measuring the single particle and collective behavior of plasmas at densities expected in ALCATOR. Another area of active research is the design of divertors for torodial thermonuclear reactors.

In the area of materials, Professor Arden L. Bement and interested students have been studying the materials requirements for advanced power generating systems, such as open-cycle MHD and gas turbines and have investigated void formation and radiation induced growth in metals.

In view of the increasing debate over the environmental and safety aspects of nuclear power, Professors Benedict, Rasmussen, and Rose have participated in several forums to inform the public of their views. Another area of growing interest to faculty and students is the role of nuclear energy relative to other sources of energy for societal use. Professors Benedict, Golay, Mason, Rasmussen, and Rose have all spent appreciable time participating in various considerations of policy alternatives for the production and use of energy. New subjects of instruction and research interests have developed as a result.

Student enrollment in September, 1971, was 118 students, up slightly from the previous year, but down from the previous level of 125-130. A total of 48 new students enrolled during 1971-72. The AEC has continued to phase out their Fellowship and Traineeship program so that the general level of financial support of students in the Department continues to decline. In the spring of 1972 the AEC started two new smaller traineeship programs in Nuclear Environmental Engineering and in Applied Radiation Protection and awarded three of each type to the Department. The level of application for admission remained constant at 90 this year with two-thirds of these from the United States and one-third from abroad.

EDWARD A. MASON

## Department of Ocean Engineering

The Department has completed its first year under its new name, Ocean Engineering, culminating a half-decade of progress in broadening its objectives and programs. The changes have been well received but, in contrast to other well-established names in engineering, the Department faces the need to define ocean engineering and to tell its story to potential students, to alumni, and to professional colleagues. The Department continues its commitment to naval architecture and marine engineering, and is both proud of and grateful for the strong program in this field that has served as a base for expansion. The Pratt School of Naval Architecture and Marine Engineering will continue to be operated as an integral part of the Department.

Ocean engineering has to do with large-scale physical facilities or systems designed, built, or operated in or for the oceans. Greater specificity in this description is achieved by addressing areas of application, that is, market areas for ocean engineering skills. The ocean engineering aspects now included in the Department's education and research program are: ocean transportation, ocean defense systems, offshore fossil fuels, offshore minerals, marine food, coastal zone development, environmental protection, oceanic waste conversion, marine recreation, and oceanographic systems. Most of these areas intersect broader programs of the Institute, and the Department finds collaboration both natural and effective.

Another view of ocean engineering may be based on its component disciplines. Those

disciplines or technologies necessary to actually carry forward or to provide the basis for programs in the various application areas, and which are now represented in the Department's faculty and related staff are: ship, rig, and platform design; systems engineering; probabilistic modeling; economics, public policy, and law; production and management; propulsion and power; control engineering; instrument, sensor, and gear technology; materials and fabrication; hydromechanics; thermodynamics; structural mechanics and dynamics; acoustics, vibration and shock; physical, chemical and biological oceanographic engineering. The Department continues to develop its human resources by faculty additions, by collaboration with other M. I. T. departments, by joint programs with other institutions, and by visiting staff.

In realistic terms faculty increases cannot outstrip student body increases. At the same time the student body should not outdistance job opportunities. At this stage outlooks in ocean engineering, including naval architecture and marine engineering, continue to be favorable. The challenge to the Department is therefore to realistically sense opportunities, to attract a capable and properly sized student body, to develop and maintain a viable program, and to add faculty as needed on a selective basis. In these times of Institute, as well as national, budget constraints, it will also be a challenge to grow in a healthy manner, if indeed the opportunity for growth continues to be sensed as strongly as it is now.

In recent years considerable emphasis has been placed on the development of the graduate program. This year emphasis shifted to the undergraduate program. Of special note is the successful two-term sequence 13.001 and 13.002, Marine Applied Mechanics, intended for sophomores, which presents a unified approach to both hydrodynamics and structural mechanics. Undergraduates concluding this sequence have been able to compete successfully in related graduate subjects, thus providing the undergraduate curriculum with efficiency as well as unity. Also of special note is 13.90, Ocean Engineering Laboratory, which provides undergraduates with direct experience in engineering for the ocean environment. Projects are planned in the preceding academic year under 13.U.R., Undergraduate Research Opportunities, and carried out each summer in Penobscot Bay, Maine, with the cooperation of the Maine Maritime Academy. Their facilities and students are important to the Laboratory, since our students gain experience in handling boats and in interacting with pragmatic colleagues, as well as with engineering projects.

Also added to the undergraduate program are 13.79, Applied Ocean Engineering, and 13.93, Evolution and Utilization of Marine Resources. Both subjects reflect the Department's broadened objectives and provide a wider range of educational opportunities for undergraduates.

A new graduate subject, 13.27, Ocean Engineering Power Systems, was developed and offered for the first time this year. This subject covers the provision of power in ocean systems other than ships, and fills an important sector of the overall Department program in marine power systems. Another new graduate subject, 13.63, Transportation Systems Inventory Control and Reliability, fills an important need in the shipping management program of the Department.

The Department has moved toward a single degree, Ocean Engineer, to replace the four now available at the Engineer level. This will avoid often meaningless distinctions and will hopefully lend greater status to the degree. Graduate students entering in September, 1973, and thereafter will come under this ruling.

Department faculty, staff, and students were engaged in over 35 funded research efforts during the 1971-72 academic year. The following samples are intended to convey the flavor of the Department's research program.

A methodology is being developed to predict the motion of surface vessels in a seaway.

Results available to date have been distributed to many designers for use in preliminary design, and have been enthusiastically received. Also reliability and safety analysis of ship structures under extreme and repeated random loads is being carried out. The philosophy, methodology, and criteria for ship structures are being summarized in text form as an advanced design tool, which should be completed shortly.

As part of the Department's program on advanced ship design, the performance characteristics of catamaran configurations are being studied, including behavior in random seas. Also, deep submersible design studies have been and are being carried out for various research or work missions.

We are developing a computer model of ship/harbor systems for analysis of collision or grounding avoidance techniques. The future of Atlantic ports based on commodity transport needs is being studied, leading to an overall assessment of relevant requirements for land transportation facilities and deep water terminals. Interoceanic canal requirements in Central America are closely related to developing industry in Japan and Australia, and to coal resources in the United States; these factors among other trends are being addressed to help understand the future of such vital oceanic links. An analysis of the ship charter market has received wide attention, since it provides market predictions based on input data covering resource, tonnage, and commodity trends.

To help meet oil pollution requirements, we are investigating the use of impermeable membranes for isolating tanker cargoes from sea water ballast. Also analytical and experimental studies continue on the design of pollution control barriers in waves and currents. In a related effort, faculty and students participated in full scale evaluations of oil barriers at sea. The impact of potential oil discoveries on New England's continental shelf is being studied; regional economic benefits, possible economic disbenefits to the fishing and/or recreation industries, and environmental risks are being described and quantified as guides to regional decision makers.

Thermal stresses and metal movement during welding greatly influence shipbuilding procedures and hull strength. These effects are under study as part of the Department's research program on welding, which also includes underwater welding and welding of aluminum structures. At the request of NASA, welding experiments in space are also being planned by Department faculty; such experiments will meet NASA needs, as well as provide basic understanding applicable to a wide range of environmental conditions.

The Department's program also includes research on the dynamics of towing cables, the hydrodynamics of slender bodies with lifting surfaces, the propagation of water waves over sedimentary interfaces, and the plasticity of plates subject to external loads such as ship slamming. Experimental and theoretical work continues on propeller design, and analytical techniques have been developed to prepare propeller lines from specified performance characteristics. Experiments have confirmed the theory of turbulent boundary layer excitation of a cavity-backed panel, as an elementary model of a sonar dome. Analytical models of fluctuations of sound in the ocean are being developed with the objective of aiding sonar system design, and possibly also of suggesting means for measuring water mass dynamics.

The student body for the year 1971-72 was constituted as follows:

| | |
|---|---|
| XIII and XIII-B | Ocean Engineering (including Naval Architecture and Marine Engineering and Shipping and Ship-building Management): 25 undergraduate and 69 graduate students. |
| XIII-A | Naval Construction and Engineering: 61 graduate students. |

XIII-W Joint Program in Ocean Engineering with Woods Hole Oceanographic Institution: 8 graduate students.

While sharp distinctions are not possible, approximately 50 students in Courses XIII and XIII-W are following degree programs in ocean engineering that have been established only within the last several years.

The undergraduate enrollment is the highest since 1964, and preliminary information on freshman interest provides optimism for a significant increase in the number of undergraduates over the next few years.

The graduate enrollment increased substantially for the present year and is the highest since 1968. Admissions for 1972-73 seem to indicate that we may expect another increase next year. One of the problems facing the Department is providing financial support to the deserving graduate students now applying. As the number of students has increased, the financial aid to the Department in the form of scholarships has decreased, making the problem more acute.

The Department has established a Department Development Fund with the plan that special appeals to alumni and friends may provide resources for special purposes. In contrast to most departments at M. I. T., the Department of Ocean Engineering has very little uncommitted or undesignated funds available to it. The Department has recognized that it is in need of research and field equipment to match its expanding ocean engineering program. Toward this end, the Department Development Fund will be used initially to improve the Department's research capability.

## Francis Russell Hart Nautical Museum

Special museum exhibits during the past year have featured the students' summer projects in Maine; deep sea mining; Professor Eric Mollö-Christensen's (Department of Meteorology) buoy system for air-sea studies; the art of rigging and sailmaking; a new theory of the wake of a propeller; and French undersea research.

In December, 1971, the Curator learned to his dismay that even ship models can suffer collision damage. The net results, however, were pleasant and the large model of the United Fruit Company's Santa Marta, formerly in a dingy case on the third floor, is now exhibited in the museum lobby in a well-lighted Institute-provided case.

The year's major acquisitions included a model of a dory constructed by Roderick Matheson, formerly in the Department's shop, a working model of a single-cylinder steam engine of 1880 for a tugboat, and a model of Donald McKay's clipper ship Sovereign of the Seas.

Through the year there have been, as usual, questions of all types to answer and a continuing interest in the museum's plan files which equal those of many larger institutions. Arrangements were concluded with a plan donor and Institute officials to permit the release of previously restricted plans for the construction of yachts by qualified individuals.

In September, 1971, the Barre Publishers, Inc., brought out C. J. A. Wilson's Ships, a collection of etchings taken largely from the museum's files with text by the Curator. Illustrations were supplied for five other books and one quarterly journal. The museum's model of McKay's clipper Flying Cloud will be featured in a forthcoming advertisement of a national moving company.

IRA DYER

## Center for Advanced Engineering Study

During the past year the Center for Advanced Engineering Study continued to offer at M.I.T. both the Practicing Engineer Advanced Study Program for men and women from government, industry, and other academic institutions and, in cooperation with the M.I.T. Department of Political Science, the Systematic Policy Analysis Program for men and women from the U.S. government. Both programs are normally one academic year long, although Fellows have been accepted into the Advanced Study Program who only spend one term at M.I.T.

The technical backgrounds of the Fellows in the Advanced Study Program included: chemical engineering, electrical engineering, aeronautical engineering, mechanical engineering, civil engineering, metallurgy, and physics. Their ages ranged from 27 to 59, and many were technical managers. Fellows came to the Center from the Ministry of Public Works (Mexico City); Maine Maritime Academy; Cabot Corporation; Communications Research Center (Canada); NASA Ames Research Center; Norsk Hydro Research Labs (Norway); Chiyoda Chemical Engineering & Construction Company (Japan); Hewlett-Packard; Georgia Institute of Technology; The Timken Company; Electronique Marcel DASSAULT (France); IBM; Eastman Kodak Company; Nippon Mining Company (Japan); Hitachi Ltd. (Japan); Whirlpool Corporation; Mitsui Shipbuilding & Engineering Company (Japan); and Ishikawajima-Harima Heavy Industries Company (Japan).

The Center continued to offer a number of special subjects specifically developed for Fellows in the Advanced Study Program. Although these subjects were not required, most Fellows attend one or more of them each term. Ten of the 19 Fellows arrived at the Center in July in order to take Calculus Revisited, an intensive six-week review of mathematics.

In order to tailor the program of each Fellow in the Systematic Policy Analysis Program to his specific needs and those of his agency, more freedom was given than in the previous years to attend either special subjects offered by the Center or regular Institute graduate and undergraduate subjects. Agencies sending Fellows included: the Veterans Administration; Department of Agriculture (2 Fellows); Defense Industrial Supply Center; Department of State (2 Fellows); U.S. Army; Postal Service; Department of Health, Education and Welfare; and the Navy Electronics Laboratory Center. The ages of the Fellows in this program ranged from 27 to 45.

The academic year 1971-72 was the first full year that C.A.E.S. Self-Study Subjects were available for distribution. Only two subjects, Calculus Revisited (Part I) and Probability, had been available during the previous year; three new subjects were added to the list this year including Calculus Revisited (Part 2), Random Processes, and Colloid and Surface Chemistry (Part I - Surface Chemistry). This expanded list of subjects resulted in a significant increase in the total number of organizations using our subjects and in the total number of students. This year 16 organizations (vs. four last year) and 1,147 students (vs. 228) utilized the self-study subjects.

In addition to the continued use of our subjects off-campus by industrial organizations and on-campus in the Center's Advanced Study Program and in regular Institute subjects, two experiments were undertaken in an attempt to make our subjects more widely available. Calculus Revisited (Part I) was offered to the public over educational television (WGBX, ch. 44) in Boston with a nominal registration fee covering texts and study guides. This experiment met with only limited success, around 40 registrants. However, since we know that there were at least several full high-school classes watching the program without registration, there was no way to determine how many non-registered students there were. The second experiment involved a cooperative effort with the M.I.T. Alumni Center of New

York to offer Block 1 of Probability. Classes were held after work hours in New York City and, we suspect because of this, only a small turnout was achieved.

Through an intensive program of equipment preventive maintenance, the operational reliability of the C. A. E. S. closed-circuit television (CCTV) facilities were improved so that no recording session had to be cancelled because of equipment failures during the past year. Additional control room equipment was installed and two more C. A. E. S. classrooms were fitted with TV monitoring equipment, increasing the number of our classrooms so equipped to four.

Conversion of the C. A. E. S. CCTV facility from black and white to color was initiated in February, 1972. New color cameras, color switching equipment, increased studio lighting, and a two-inch, quad color, video tape recorder are being installed. This installation should be completed during the summer of 1972.

WILBUR B. DAVENPORT, JR.

## Center for Policy Alternatives

During the last 20 years M. I. T. 's School of Engineering has become strong in those fields of applied science and engineering that relate to the extension of man's physical capabilities, particularly in those fields which undergirded the national programs for space, defense, nuclear energy, and health. The School of Engineering, like M. I. T. and the nation as a whole, now faces the challenge of applying more of its resources to the crucial problems of our changing society. In order to do so, it must provide better mechanisms for connecting the School with these problems, for informing faculty and students of their character, importance and consequences, and for encouraging faculty and students to work on such problems. Students seek new directions, and some of them strive to relate their intelligence and learning more directly to the newly perceived problems of our times. It is likely that increasing financial support will be redirected in part toward those complex problems related to the newer needs of the changing society in which we live.

This spring, as part of a plan to meet these needs, Dean Alfred H. Keil established the Center for Policy Alternatives within the School of Engineering. This Center will conduct rational study and analysis of issues, not only with the aim of suggesting alternatives and finding new ways to beneficially connect technology and social and economic welfare, but also of influencing some of the interests and programs of its own faculty and students.

This Center is chartered to study and investigate substantive issues related to society, particularly those in which technology and engineering could play significant roles. It differs from most centers for policy analysis in that, based on its studies of actual problems, it will develop a number of alternatives for action and policy and will identify possible means of implementing them. These alternatives will often be in the form of factual presentations of possible specific programs, regulations, or legislation. The implications of these alternatives will be analyzed. The Center encourages studies related to these issues in all parts of the Institute and provides a mechanism whereby students and faculty can become involved in the analyses that lead to alternatives for actions and problems and their evaluation. The Center seeks close ties and cooperation with the other Schools at M. I. T. in order to interlock with such disciplines as political science, economics, management, systems studies, architecture, and urban planning.

With the changing needs of our society for technology, this Center serves to bring new views to M. I. T., particularly to the School of Engineering, stimulating some of the faculty and students to participate in activities which have the greatest potential to social or economic utility.

The first major study which the Center will undertake is sponsored by the National Science Foundation (NSF) problem-oriented research program called RANN--Research Applied to National Needs. This study which runs for two years is directed at improving the servicing, reliability, and maintenance of consumer durables and will be conducted jointly by the Center and the Charles Stark Draper Laboratory. The study's aim is to provide the basis for exploring in the future the reduction of service costs in terms of the product's entire life cycle, including such pre- and post-purchase phases as design, quality control, safety, and environmental effects. Future studies at the Center will include a study of alternative approaches to engineering education; professional manpower markets for physical scientists, lawyers and teachers, and the economic factors affecting the higher education system as an employer and supplier of professional manpower; the mechanisms and policies by which technological change is systematically supported in Western Europe, Canada, and Japan.

J. HERBERT HOLLOMON

# School of Humanities and Social Science

## Registration Statistics

The enrollment figures in Table I, in a form that has been standard for many years, show primarily the registrations in subjects acceptable for satisfying the General Institute Requirements in Humanities and Social Science. The table also includes certain other undergraduate registrations - from thesis to elementary and intermediate foreign languages. It does not include, however, certain undergraduate subjects, mostly in economics, that are offered primarily for majors and are not eligible for credit toward General Institute Requirements. Nor, of course, does Table I include enrollments in graduate subjects.

The relative ranking of all 12 fields are shown in Table II, together with the history of those relationships for the last eight years. Table III shows the numbers of students majoring in the various departments of our School. Tables IV and V show how the undergraduate majors in the various Schools divide their choices among the various elective fields of the junior and senior program in Humanities and Social Science.

TABLE I REGISTRATION IN HUMANITIES, LANGUAGES, AND SOCIAL SCIENCE UNDERGRADUATE SUBJECTS, 1971 - 72

| | Fall | | Spring | |
|---|---|---|---|---|
| Freshman program | | 998[1] | | 940[1] |
| Sophomore program | | | | |
| Literature | 226 | | 146[2] | |
| Philosophy | 169 | | 102 | |
| History | 221[3] | | 291 | |
| Anthropology | 119 | | 177 | |
| Music | 277 | | 206 | |
| Social science | 86 | | 80 | |
| | | 1,098 | | 1,002 |
| History | 288 | | 233 | |
| Philosophy | 254 | | 172 | |
| Literature | 445 | | 388 | |
| Music | 207 | | 288 | |
| Anthropology | 51 | | 98 | |
| Interdisciplinary | 261 | | 200 | |
| TOTAL HUMANITIES ELECTIVES | | 1,506 | | 1,379 |

1 Includes registration in special humanities subjects in French (fall, 28; spring, 27).

2 Includes registration in comparable subjects in French (spring, 16).

3 Includes registration in comparable subjects in French (fall, 16).

| Table I (cont'd) | | Fall | | Spring |
|---|---|---|---|---|
| Economics | 553 | | 607 | |
| Political science | 331 | | 228 | |
| Labor relations | 81 | | 85 | |
| Psychology | 473 | | 667 | |
| TOTAL SOCIAL SCIENCE ELECTIVES | | 1,438 | | 1,587 |
| Foreign literatures and linguistics[4] | | 191 | | 141 |
| Visual arts[5] | | 355 | | 394 |
| Thesis | | | | |
| Economics | 4 | | 15 | |
| Political science | 5 | | 10 | |
| Course XXI | 4 | | 40 | |
| | | 13 | | 65 |
| English composition | | 22 | | 23 |
| Senior seminar (XXI) | | 27 | | - |
| Science writing | | 12 | | 28 |
| Elementary and intermediate foreign languages | | 284 | | 214 |
| GRAND TOTAL | | 5,944 | | 5,773 |

[4] Exclusive of 498 registrants in elementary and intermediate languages (fall, 284; spring, 214), but includes registrants in advanced languages (fall, 37; spring, 51).

[5] Taught by faculty of the School of Architecture and Planning.

TABLE II PERCENTAGE DISTRIBUTION OF JUNIOR AND SENIOR ELECTIVES IN HUMANITIES, FOREIGN LITERATURES, AND SOCIAL SCIENCE, BY FIELDS, 1964 - 1972 *

| | 1971-72 | 1970-71 | 1969-70 | 1968-69 | 1967-68 | 1966-67 | 1965-66 | 1964-65 |
|---|---|---|---|---|---|---|---|---|
| Economics | 16.6 | 13.7 | 15.1 | 15.3 | 18.1 | 21.9 | 22.8 | 19.9 |
| Psychology | 16.3 | 20.8 | 19.6 | 19.5 | 19.0 | 18.1 | 16.6 | 20.2 |
| Literature | 11.9 | 10.1 | 10.3 | 8.4 | 9.8 | 11.1 | 12.7 | 12.5 |
| Visual Arts[1] | 10.7 | 10.7 | 8.8 | 7.0 | 7.3 | 6.7 | 6.4 | 4.8 |
| Political Science | 8.0 | 6.4 | 7.5 | 10.5 | 9.8 | 9.6 | 9.2 | 9.3 |
| History | 7.5 | 8.0 | 12.6 | 10.5 | 8.3 | 9.1 | 10.2 | 8.5 |
| Music | 7.1 | 4.2 | 7.0 | 6.4 | 7.1 | 7.2 | 7.7 | 8.9 |
| Interdisciplinary subjects | 6.6 | 16.1 | 8.8 | 11.2 | 7.8 | 5.2 | | |
| Philosophy | 6.1 | 4.5 | 5.7 | 6.9 | 7.5 | 6.9 | 9.3 | 9.1 |
| Foreign Lit. & Linguistics[2] | 4.7 | 3.7 | 2.2 | 2.6 | 3.2 | 1.9 | 2.7 | 4.3 |
| Labor Relations | 2.4 | 1.7 | 2.4 | 1.7 | 2.1 | 2.0 | 1.9 | 2.1 |
| Anthropology | 2.1 | | | | | | | |

* Omitting registrations in the Freshman and Sophomore programs and in the miscellaneous fields following Visual Arts in Table I.

1 Taught by faculty of the School of Architecture and Planning.

2 Exclusive of elementary and intermediate language subjects; includes advanced language subjects.

TABLE III MAJORS IN THE SCHOOL OF HUMANITIES AND SOCIAL SCIENCE*

| | Undergraduates | | | Graduates | | | | |
|---|---|---|---|---|---|---|---|---|
| | Social Science | Humanities | TOTAL | Social Science | Humanities | Foreign Literatures | TOTAL | GRAND TOTAL |
| 1955-56[1] | 40 | 19 | 59 | 52 | — | — | 52 | 111 |
| 1956-57 | 38 | 32 | 70 | 69 | — | — | 69 | 139 |
| 1957-58 | 41 | 67 | 108 | 74 | 1[3] | — | 75 | 183 |
| 1958-59[2] | 46 | 75 | 121 | 81 | 1[3] | — | 82 | 203 |
| 1959-60 | 38 | 64 | 102 | 105 | 2[3] | — | 107 | 209 |
| 1960-61 | 35 | 93 | 128 | 114 | — | — | 114 | 242 |
| 1961-62[4] | 55 | 88 | 143 | 129 | — | 7 | 136 | 279 |
| 1962-63[5] | 65 | 85 | 150 | 145 | — | 22 | 167 | 317 |
| 1963-64 | 71 | 87 | 158 | 165 | 4 | 31 | 200 | 358 |
| 1964-65[6] | 78 | 109 | 187 | 190 | 15 | 36 | 241 | 428 |

| | Economics | Political Science | Philosophy | | Economics | Political Science | Psychology | Philosophy | Linguistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965-66 | 50 | 60 | 114 | | 224 | 111 | 63 | 23 | 24 | 34 | 255 | 489 |
| 1966-67 | 76 | 73 | 121 | | 270 | 117 | 79 | 26 | 29 | 42 | 293 | 563 |
| 1967-68 | 81 | 76 | 148 | | 305 | 114 | 80 | 27 | 27 | 31 | 279 | 584 |
| 1968-69 | 84 | 79 | 195 | | 358 | 118 | 87 | 27 | 23 | 38 | 293 | 651 |
| 1969-70 | 68 | 85 | 200 | | 353 | 117 | 82 | 41 | 31 | 41 | 312 | 665 |
| 1970-71 | 60 | 59 | 162 | | 281 | 103 | 78 | 23 | 36 | 34 | 274 | 555 |
| 1971-72 | 63 | 38 | 124 | 13 | 238 | 104 | 70 | 29 | 29 | 40 | 272 | 510 |

* As registered in the second term of academic year 1955-56 to 1971-72 (omitting freshmen and undesignated sophomores).

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 IV DISTRIBUTION OF REGISTRANTS IN UNDERGRADUATE ELECTIVES BY SCHOOLS AND FIELDS (BY NUMBERS), 1971-72

| School | Economics | Labor Relations | Political Science | Psychology | Subtotal in the Social Sciences | History | Literature | Music | Philosophy | Anthropology | Interdisciplinary Subjects | Visual Arts | Foreign Literatures | Subtotal in the Humanities | GRAND TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Architecture | 67 | 2 | 37 | 50 | 156 | 14 | 38 | 15 | 8 | 11 | 35 | 222 | 3 | 346 | 502 |
| Engineering | 412 | 79 | 87 | 304 | 882 | 150 | 106 | 120 | 55 | 20 | 92 | 126 | 66 | 735 | 1,617 |
| Humanities | 99 | 31 | 196 | 74 | 400 | 121 | 261 | 83 | 123 | 44 | 106 | 48 | 43 | 829 | 1,229 |
| Management | 59 | 18 | 34 | 44 | 155 | 26 | 29 | 15 | 6 | 3 | 16 | 27 | 5 | 127 | 282 |
| Science | 243 | 21 | 59 | 403 | 726 | 154 | 280 | 198 | 196 | 38 | 132 | 177 | 129 | 1,304 | 2,030 |
| Unclassified[1] | 280 | 15 | 146 | 265 | 706 | 56 | 119 | 64 | 38 | 33 | 80 | 149 | 86 | 625 | 1,331 |
| TOTAL | 1,160 | 166 | 559 | 1,140 | 3,025 | 521 | 833 | 495 | 426 | 149 | 461 | 749 | 332 | 3,966 | 6,991 |

[1] This includes all students who have not yet made Course designations, Wellesley students, and a few unclassified graduate students.

TABLE V RELATIVE DISTRIBUTION OF REGISTRANTS IN UNDERGRADUATE ELECTIVES BY BROAD FIELDS AND BY SCHOOLS INSOFAR AS THEY CAN BE IDENTIFIED, 1971-72

| School-Field | Visual Arts | Foreign Literatures and Linguistics | Other Humanities | Social Sciences |
|---|---|---|---|---|
| Architecture | .44 | .01 | .24 | .31 |
| Engineering | .08 | .04 | .34 | .54 |
| Humanities | .04 | .04 | .60 | .32 |
| Management | .09 | .02 | .34 | .55 |
| Science | .09 | .06 | .49 | .36 |

ROBERT L. BISHOP

## Department of Economics

This year was not one of major initiatives, but more one of consolidation of changes that were instituted previously.

### Undergraduate Program

More bachelor's degrees in economics will be awarded this year than in any year since the inception of the program. This can be attributed partly to the increase in numbers of students receiving two (or more) degrees simultaneously. Since 1970, the percentage of our undergraduates who received a second degree from another department rose from 11 to 33 percent, three-quarters in the Schools of Engineering and Science. While modest in scale, the expansion in the number of students seriously combining a natural and social science is encouraging.

No major changes were made in the program for economics majors. The area in which our success is most variable is in research training and experience. We plan to continue experimentation next year to determine what procedures and format are most fruitful.

The economics portion of the humanities program is also being reexamined in the light of enhanced interest in the economic aspects of social problems such as the environment, energy, health, and the city.

### Graduate Program

Last year we instituted several changes in the graduate core subjects as a means of providing greater flexibility to cope with the differing backgrounds of our entering students and to permit greater self-pacing. In general, these have been successful innovations. The period from entrance to the general Ph. D. examination was reduced by at least one full term for more than a third of last year's entering class, compared with no more than 10 percent in previous classes.

Financial support this coming year will be more stringent than it has been for a decade, despite the fact that we will have half of the total national NSF fellows in economics in the entering class. We are making every effort to expand the number of research assistantships as one means of meeting the problem.

Last year we had the fourth largest number of black graduate students in economics in the country according to a study made by the Black Economists' Development Project. Special tutorial programs have been arranged to fill gaps in their backgrounds, the pace of their programs has been dealt with flexibly, and their progress has been satisfactory.

The job market was better for our Ph. D. 's than it was last year although again it was a slow one. Of the 25 available students, 22 went to university posts (of which 3 were research positions and 3 were foreign), 2 to private research organizations, and 1 to the government.

## Research Activities

The major area of research concentration continues to be in the urban field. The development of an econometric model of Boston focused on metropolitan location of economic activities has involved five faculty, and many graduate and undergraduate students. Other closely allied work has focused on an historical analysis of influences on land values in Boston and on the pure theory of location and land use.

Another identifiable area in which several faculty and students are engaged is human resources: returns to education, factors affecting the supply and quality of labor, the operation of labor markets for different economic groups, the problem of information, turnover and job search, migration and the effects on the distribution of income.

More work has been carried forward in areas of interest to other departments and disciplines. In addition to those indicated above, particular mention should be made of the many industrial studies, such as copper, oil, television; environmental and ecological problems; and the relationships between law and economics.

In addition to these areas, a wide range of individual research interests continues in exchange controls and economic development; in statistical, econometric, and economic theory; and in their application to applied problems.

## Personnel

Visiting faculty consisted of Professors Pranab K. Bardhan of the Indian Statistical Institute, Albert G. Hines of Durham University and Helmut Schuster of the Technical University of Berlin. Dr. Phyllis A. Wallace of the Metropolitan Applied Research Center lectured on urban problems in the spring term.

An unusually large number of faculty were on leave: Professors Morris A. Adelman, to complete his study of the oil industry; Evsey D. Domar, to carry out research on comparative economic systems and to lecture at the Stockholm School of Economics; Richard S. Eckaus, to conduct research on Latin American capital markets at the University of California at Berkeley; Charles P. Kindleberger, to conduct research in European economic history at the Universities of Kiel and Rome; and Edwin Kuh, to further expand the use of TROLL at the National Bureau Computer Research Center in Cambridge.

Professors Domar and Kindleberger have become the first holders of the chairs given by the Ford Foundation in international studies. Assistant Professor Robert W. Crandall was promoted to Associate Professor. Assistant Professors Edel and Ronald E. Grieson have accepted positions at Queens College, City University of New York.

Assistant Professor Matthew D. Edel was made a mamber of the National Steering Committee of the Union of Radical Political Economists; Professor Franklin M. Fisher was elected to the Council of the Econometric Society; and Professor Robert M. Solow to the National Academy of Sciences. Professor Solow also gave the first Frank W. Paish Lecture to the Association of University Teachers of Economics in the United Kingdom and received an honorary doctorate from Brown University. Professor Paul A. Samuelson received honorary doctorates from Keio University, University of Massachusetts, University of Rhode Island, and Harvard University.

Professor Everett E. Hagen reached retirement age this year. While he will be with the East-West Center at the University of Hawaii next year, he will return as a Senior Lecturer. Professor Hagen came to the Center for International Studies and to the Department as Visiting Professor becoming Professor in 1959, and a joint Professor in Political Science and Economics in 1965. He has had a distinguished career as a teacher, as a contributor to knowledge

through his research on problems in economic development that lie beyond economics, and as an advisor to governments throughout the world. Following the untimely death of Professor Max F. Millikan, he agreed to step in as Director of the Center at a difficult time and kept things operating smoothly.

Professor Paul N. Rosenstein-Rodan has now served his full five years as Senior Lecturer following retirement. We regret his leaving, but we are pleased that he continues as a neighbor in developing a Latin American study center at Boston University.

E. CARY BROWN

## Department of Foreign Literatures and Linguistics

### Program in Linguistics

Professor Noam Chomsky was on sabbatical leave this year, doing research on problems in the theory of syntax and semantics. He was awarded a Guggenheim Fellowship and was elected to the National Academy of Sciences. Three books of his were published: Problems of Knowledge and Freedom, Studies on Semantics in Generative Grammar, and an enlarged edition of Language and Mind.

Professor Hubert Matthews will be on sabbatical leave in 1972-73. He plans to spend the year at the Crow Agency School in Montana, where he will develop bilingual and bicultural materials for all courses covering the first four grades of instruction for Indian children.

Professor David Perlmutter will also be on leave next year. During the fall term he will be teaching in Vincennes, France, and will be doing research on French syntax in the light of universal grammar. In the spring and summer he will be doing research in Japan on Japanese syntax. His book, Deep and Surface Structure Constraints in Syntax, appeared in 1971.

Professor Catherine Chvany has just completed the manuscript of a book entitled On the Syntax of Existential Sentences in Russian.

The research in progress of the linguistics faculty continues to be extremely diversified. An impression of its range may be derived from the subjects of investigation already mentioned, plus the following: Professor Morris Halle -- Russian accentology, the bases of phonetics (with Professor Kenneth Stevens), the role of the lexicon in a grammar, the character of the processes that govern word formation, and the linguistics theories of the Prague School; Professor Matthews -- a sketch of Hidatsa grammar, syllabic and alphabetic orthographies for Eskimo, materials for teaching literacy in Eskimo, and materials for teaching the structure of Lakota; Professor Kenneth Hale -- syntactic, semantic, and phonological universals in American Indian and Australian Aboriginal languages, and the relevance of linguistics to bilingual education in American Indian communities, especially Navajo and Passamaquoddy-Maliseet; Professor Paul Kiparsky -- phonology, historical linguistics, and Pāṇini (with Visiting Professor Shivaram Joshi); Professor John Ross -- a non-discrete, but formal, theory of grammar; Professor James Harris -- general phonological theory, Romance linguistics, and Spanish phonology and morphology; Professor Catherine Chvany -- Russian syntax, lexical entries as a function of theory, the use of diminutives as a stylistic device in Leskov, and pedagogical materials for intermediate Russian.

The undergraduate program in linguistics, initiated in 1970-71 with a subject offered by Professor Harris (23.700J, Language and Its Structure) has been expanded this year to include two more subjects: 23.952, Structure of Russian, given by Professor Chvany, and 23.953, History of Russian, given by Mr. Channon.

### Program in Foreign Languages and Literatures

Two books by Professor Krystyna Pomorska were published by The M.I.T. Press in 1971: Readings in Russian Poetics: Formalist and Structuralist Views (with L. Matejka) and Fifty Years of Russian Prose: From Pasternak to Solzhenitsyn. She is now preparing two full-length studies, one to be entitled Pasternak's Invariants and Variables, the other on Solzhenitsyn prose.

Professor Martin Dyck is composing an extensive work to be called A New Theory of Comedy. He has accepted the post of associate editor on the new international, multilingual journal, Historia Mathematica.

Professor Robert Jones has almost completed his volume on Gérard de Nerval for the Twayne World Authors Series. He is also making progress on his analysis of the plays of Jean Giraudoux.

Professor Eugene Nelson is preparing a book on the didactic theater. Both he and Mr. Channon have continued to serve as freshman advisers this year.

At the invitation of the School of Management, Professor William Bottiglia taught subject 15.183, Readings in Power and Responsibility, to the Sloan Fellows in the spring term. He will teach it again next spring and in the fall will offer a shorter version of the same subject to the Senior Executives.

Subject 23.051, The French Enlightenment, has been dropped from the Humanities in French program. It will be replaced next year by a new offering, Crises of Contemporary Western Society.

The Department's proposal for an undergraduate double major came before the Committee on Educational Policy toward the end of the fall term. After careful consideration, the Committee concluded, in a statement dated January 3, 1972, "that the current proposal should not be acted upon until the Institute at large and the faculty of the School of Humanities and Social Science in particular have had a full opportunity to review the role of the several humanistic disciplines at M.I.T. and to explore all of the possible ways in which those disciplines may be most effectively defined and related to each other for maximum benefit to our students. To the extent that the proposed degree program would tend officially to make more rigid the already existing divisions within the Humanities enterprise, the C.E.P. is reluctant to approve it as presently formulated."

WILLIAM F. BOTTIGLIA

## Department of Humanities

*Curriculum*

In October, 1971, Dean Bishop appointed a subcommittee of the School Council to examine various plans for the revision of the core curriculum in Humanities and Social Science. Professor Bottiglia served as chairman of this committee, whose members included Professors Liepmann, O'Neil, Pool, Solow, and James F. Thomson. Their recommendations call for the replacement of the current program with a proposal that 1) every undergraduate work out a sequence of five one-term subjects in one field; 2) that if his field of concentration is in the general area of the Humanities, he chose two one-term subjects in the general area of Social Science, and vice versa; and 3) that the curriculum in each department or principal field of the School be revised to include one or more subjects which develops that discipline

in historical perspective, and another which relates the discipline to significant contemporary issues.

The major features of this proposal would be first to abandon a commitment to a common body of freshman-sophomore options along with the commitment to interdisciplinary subjects or "general education;" and to say in effect that responsibility for the development of undergraduate programs in Humanities and Social Science be left to the several departments and to students individually.

An alternative plan, proposed by the Chairman of Humanities, would retain the principal of the core curriculum while eliminating the present distinction between the programs of the first and second year, such that options in discreet disciplines would be available to sophomores. It is clear enough that trends in liberal arts colleges are running more in the direction of the first revision, however, than toward the second. Nevertheless, a critical question still to be answered is whether the abandonment of distribution requirements in general education in the liberal arts curricula should be followed likewise at M.I.T., given the special situation of M.I.T. undergraduates in their commitment to professional training and education. The Bottiglia-Liepmann proposal also raises questions about whether undergraduate education in Humanities and Social Science should be the responsibility of the School in the future, or committed in effect to the separate determination of the six departments. Once again, departmental autonomy appears to be overtaking collective forms of curricular planning in the colleges. Differences between the disciplines have become too great, controversies on first principles too hard to compromise, and disagreements over educational goals too acute to contain. Once again, however, the specific condition of our students, including severe limits of time, poses special problems at M.I.T. Until these issues can be resolved, we cannot avoid the need for a short-step experimentation and innovation -- an effort which will surely have to occupy us again during the coming year.

Changes in the present core curriculum during the past two years have come about most notably from the introduction of the new sophomore options in Anthropology (21.06) and Music (21.07), each a one-term subject for sophomores. Total registrations in the Music option were 356 in 1970-71, and 475 in 1971-72; registrations in the introductory Anthropology Program were 236 in 1970-71 and 313 in 1971-72. Given the structure of the present requirement, enrollments in Music have reduced registrations in Literature and Philosophy, while those in Anthropology have reduced earlier registrations in History and Political Science.

The Visiting Committee on Humanities met for a day on March 9 under its new chairman, Dr. Albert H. Bowker, Chancellor of the University of California at Berkeley. The departmental presentation was primarily addressed to recent developments in Music, the writing program in Literature, and Anthropology, which now constitutes a special field of concentration in the department along with History. Literature,and Music.

In July, 1971, efforts were begun to assemble a modest collection of photographs and drawings illustrating the early history of the Institute for an exhibit planned for the inauguration of Dr. Wiesner. The exhibit was also planned to duplicate in part an exhibit illustrating the first 50 years of M.I.T. which was displayed when the Great Court was opened in 1916. In preparing for this exhibit in early September, Warren Seamans and Walter Taylor discovered quite by chance several early portraits of individuals connected with the Institute. This discovery led in turn to a systematic search over a period of eight months for other paintings, portraits, photographs, architectural drawings, busts, and Institute artifacts. A Committee on Institute Memorabilia was appointed by Howard W. Johnson in November to direct the development of a permanent collection, and a second exhibit was displayed in the Hayden Gallery between May 21 and June 22.

*Personnel*

Professor Klaus Liepmann retired in June after a uniquely constructive career of 25 years as first Professor and Director of Music at M.I.T. The quality of music at M.I.T., both in the classroom and in performance, is reflected in the details of his own valedictory report below. This program, as Dean Burchard put it, is "very much the shadow of one man." Walter Piston also observed recently that Klaus Liepmann "over the years has stood for the highest standards in the teaching and performance of music."

The final event of an exceptionally prolific musical calendar was a "Spring Festival of Music" in Professor Liepmann's honor between May 2-6. The Fine Arts Quartet presented two performances, sponsored by the Abramowitz Memorial Lecture Series: one, a Beethoven program, and the other a program which included Hayden, Bartok, and Brahms. The third concert, conducted by Professor Liepmann, was a presentation of Bach's St. John Passion by the Choral Society, the Glee Club, the Cambridge Festival Orchestra and soloists. At the end of the evening, Dr. Wiesner presented Professor Liepmann the Gordon Billard Award "for special services performed for the Institute."

The Music faculty, no less than musical culture itself at M.I.T. and in Boston, suffered a tragic loss in the death of Gregory Tucker on July 6, 1971. Professor Tucker came to the Institute in 1947. His long career was a rare combination of high artistry and musicianship with a natural talent for teaching and an uncommon gift for friendship. On November 20, 1971, a Memorial Concert took place in Kresge Auditorium in honor of Gregory Tucker before a full audience of friends. Performers included the Juilliard Quartet, John Graham, Karl Graber, Frederic Rzewski, Roman Tottenburg, Luise Vosgerchian and Ray Jackendoff. The program presented works by Beethoven, Bartok, Gregory Tucker, Bach and Mozart.

Professor Roy Lamson, Director of Course XXI, was appointed Special Assistant to the President for the Arts and was responsible for organizing and coordinating the efforts of a new Council for the Arts at M.I.T. throughout the past year. In June he received the degree of Doctor of Humane Letters from Oklahoma City University.

RICHARD M. DOUGLAS

## Anthropology

The Anthropology Program originated in a series of discussions begun three years ago. All colleagues at the Institute with backgrounds or training in anthropology were invited to meet. Our early conversations focused on the position of Anthropology in the environment of M.I.T. Skirting the issue of a precise definition of anthropology, we found through a simple poll of our interests and activities that we were almost as broadly ramified as the field of anthropology itself and at the same time articulated with many parts of the Institute. Location in the Department of Humanities, with its unifying tone, stresses the variety and creativity of human accomplishment and provides a physical and intellectual place which we feel is appropriate to our endeavor.

Because anthropology includes perspectives both biological and cultural, historical and structural and because it deals with technologically simple and complex situations using various theoretical perspectives, the discipline has much to say to students in Humanities as well as those in social sciences, particularly Economics, Political Science, and Urban Studies. We regularly have contacts with students, in our elective subjects, who major in engineering or science, who are able to have some anthropological experience relevant to their overriding interests. Fields, usually understood to be distant from anthropology, can be looked at as subsets of a complex of cultural achievements, located within certain material realities, social institutional arrangements,and shared ideas. The student of technology can

have the chastening experience of seeing his own interests refracted through different cultural and historical settings.

In the 1971-72 academic year, we offered a general introduction to Anthropology as a sophomore Institute requirement. During the course of that year we sought and obtained approval to offer an undergraduate degree in anthropology, within the Humanities options. In the first year of its operation, the Anthropology Program was staffed by Professors Christopher Boehm, Martin Diskin, Kenneth Hale, Heather Lechtman, Hubert Matthews, and Arthur Steinberg. To varying degrees, the entire staff participated in the introductory course, sharing both lecturing and sections. Professor Boehm is leaving the program and Dr. Jean Jackson has been hired as of next year (1972-73). She has completed her doctorate at Stanford University in anthropology. Her thesis is based on field work in the Colombian Vaupés among linguistically heterogeneous tropical forest horticulturalists.

In October, 1971, in discussion with three invited anthropologists representing different subfields and points of view, several guidelines were established that will shape anthropology at M.I.T. First, this program has a primary focus on undergraduate teaching. The intellectual niche occupied by anthropology at M.I.T. can only be actualized by the constant relationship to students through teaching. Second, rather than try for exhaustive coverage of anthropology, we stress the problem-orientation that grows out of each of our research interests. The point is to transmit an anthropological perspective, or analytic stance, rather than a meticulous remapping of knowledge developed to date. For certain subfields that we do not offer, such as biological anthropology, students may cross-register at Harvard University. Cross-registration with Wellesley College is of course possible and students have been using this option.

At this point, the Program has three principal intellectual foci: first, the cultural aspects of language and linguistics as well as problems of national policy toward indigenous populations (Professors Hale and Matthews); second, the study of ancient technology using archeological data-collection techniques and modern material science methods for the analysis of the artifacts recovered (Professor Lechtman has been focusing on aspects of Pre-Colombian Andean technology and Professor Steinberg on materials from Classical Mediterranean sources); and, third, the study of contemporary peasantries and the economics of non-Western peoples. Professor Diskin's continuing interest in peasant Indian markets of southern Mexico is the source of this portion of the Program. The addition of Dr. Jackson will bring another important viewpoint here, the symbolic aspect of cultural behavior.

Not all the faculty members mentioned above are full-time participants in the Program. In full-time equivalences our total staff consists of about three members. Some additional staff are needed to offer a reasonable degree of variety as well as depth of experience in the field. We hope that it will be accomplished fairly soon.

This past year has seen substantial enrollments in the sophomore introduction in the fall and in the spring. Four seniors graduated in anthropology and five senior theses were directed through the Program. Students have responded well to the Program and all indications point to growing interest.

At a time when the critical evaluation of technology is being called for, when Humanities is less than content with merely a service role, anthropology, "the most scientific of the humanities, the most humanistic of the sciences," has an important contribution to make to undergraduate education at M.I.T.

MARTIN DISKIN

## Literature Section

During the past year the number of students enrolled in creative writing subjects continued to increase at a steady rate. The creative writing faculty responded by offering an expanded number of writing subjects and sections within each subject by arranging student-faculty readings (in addition to readings by visiting writers), and by organizing writing workshops during the Independent Activities Period. Because Tom Cole resigned to devote himself full-time to his work in movies, James Baker Hall was appointed to teach in the writing program during the spring term.

The problem of exactly what role creative writing should play in the literature curriculum is one that the section has not faced directly. It is one of the general curricular questions that we will be dealing with in biweekly section meetings during the coming year.

*Personnel*

Members of the section continue to be active in a wide variety of ways. For example, Barry Spacks recently had two books published: Something Human (a book of poems) and Orphans (a novel), both by Harpers Magazine Press. Eugene Goodheart presented two of the Gauss Seminars at Princeton University. His two papers were entitled "Utopia and the Irony of History" and "Imagination and the Temptation of Politics." Alvin Kibel spent the spring term as a Fellow at the Center for Advanced Study in the Humanities at Wesleyan University. Albert R. Gurney, Jr. won the Drama Desk Award for his play, Scenes from American Life, from New York theater critics in November. Louis Kampf finished his term as President of the Modern Language Association at the Association's annual Christmas time meeting and his (and Paul Lauter's) collection of dissenting essays on the teaching and study of literature, The Politics of Literature, was published in the spring (Pantheon). Michael Folsom published a volume of Mike Gold's work (International Publishers).

In addition to these examples of our faculty's activities outside the Institute, it is useful to note their activities within the Institute but outside the department and section. Members of the section were involved in all three of the Institute's experiments in lower division education: Travis Merritt and Nancy Dworsky in the Concourse Program; Peter Elbow and Michael Miller in Experimental Study Group; and Joseph Brown in Unified Science Study Program.

WAYNE O'NEIL

## History Section

Throughout the year the Section continued to discuss its identity, purpose, and aspirations despite a markedly ambiguous institutional and educational policy context arising from the changing leadership of the School and widespread reconsideration of the future shape of the whole Institute humanities requirement. The still rather tentative and incomplete conclusions that grew out of the discussions should nevertheless help the Section take a significant role in the shaping of the future. With regard to educational focus it was decided that this should be emphatically in the area of the teaching of undergraduates. Aspirations toward a graduate program are to be at least postponed indefinitely. In view of this the Section decided to deemphasize, though not necessarily to abandon, its former rather exclusive emphasis on the analytical study of modernity and modernization viewed in comparative and global perspective. While some important curriculum emphasis of this sort would be kept, the Section will henceforth pay more direct attention also to regional studies (United States, Western Europe, the Communist world, the developing countries). At the same time, the more analytical or thematic dimension of the program would be somewhat re-oriented in order to do more with such subjects, very relevant to M.I.T., as industrialization, the history of technology and of science. By way of implementation of these ideas a number of committees of appropriate specialists are being formed to elaborate the various

strands of a new curriculum. Several new subjects designed to help specify that curriculum, are already in the offing. There are two on the European region: Europe, 1848-1919: Nationalism, Liberalism, Democracy, and War; and Europe, 1917-1948: The Era of Mass Politics. A new two-term subject, Latin American Social History, will also add a new opportunity for regional study. It is hoped that still another new offering, Industrialization, Technology, and Social Change in Western Europe and America, 1750 to the Present, will play an important role in establishing a firmer curricular center for our several more specialized offerings on like topics so germane to the Institute at large.

The Section also made some concerted efforts to improve its part of Course XXI. Henceforth the History Seminar, now subtitled Problems of Historical Inquiry, will be offered to juniors in their second term rather than to seniors in their first. Open to any interested students, the new seminar will involve the teaching of selected topics and problems by a number of staff members rather than only one as in the past. The purposes of this are several: to make possible improved faculty-student relations; to illustrate better the complexity and scope of historical studies; to help Course XXI students begin earlier consideration of their senior theses. In respect to theses the Section also initiated some new procedures involving closer supervision and the reading of and commenting on the finished products by two or three faculty members instead of only the student's thesis adviser.

Professor Fernando Henriques of the University of Sussex returned as visiting professor in the fall term and taught a subject on comparative racial history. The Section had the further good fortune of a brief visit in the spring by Dan Avni-Segre of St. Anthony's College, Oxford, who led a most stimulating seminar discussion on contemporary Israeli politics.

## Humanities and Engineering XXI-A; Humanities and Science XXI-B, Program 1; Humanities and Science XXI-B, Program 2

In the spring term of 1971-72 the enrollment in Course XXI was 132, compared to 185 in 1970-71, and 228 in 1969-70 (the highest enrollment since 1955). The decline in numbers of students is due in part to fewer registrations for second degrees in Course XXI (30 in 1969-70; 19 in 1970-71; and 6 in 1971-72); some of the reasons for this change may be sought both in our national economy and in reduced draft calls. Reputed overproduction of graduate degrees in Literature and History have also influenced some students to choose other fields or not to enter graduate study. Moreover, students enrolled in Philosophy in Course XXI-B, Program 2, transferred to Course XXIV, which began its separate curriculum in the fall of 1971.

Once again Literature leads the disciplines in numbers enrolled. The following brief table indicates the enrollment by disciplines: Literature -- 59; History -- 23; Music -- 19; Social Inquiry -- 10; Anthropology -- 9; Philosophy -- 8; and Major Departure -- 4.

Further detail is given in the following summaries:

COURSE ENROLLMENT SPRING 1972

| | By Disciplines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Anthropology | History | Literature | Music | Philosophy | Social Inquiry | Major Departure | Sub-Total | Total |
| XXI-A | | 6 | 4 | 6 | 1 | 1 | | 18 | |
| XXI-B, 1 | 2 | 5 | 16 | 5 | 7 | 9 | | 44 | |
| XXI-B, 2 | 7 | 12 | 39 | 8 | | | 4 | 70 | |
| | | | | | | | | | 132 |

COURSE ENROLLMENT SPRING 1972

By Classes

| | Anthropology | History | Literature | Music | Philosophy | Social Inquiry | Major Departure | Sub-Total | Total |
|---|---|---|---|---|---|---|---|---|---|
| Seniors (65) | | | | | | | | | |
| XXI-A | | 5 | 1 | 1 | | 1 | | 8 | |
| XXI-B, 1 | 1 | 3 | 5 | 4 | 5 | 3 | | 21 | |
| XXI-B, 2 | 3 | 8 | 19 | 3 | | | 3 | 36 | |
| | | | | | | | | | 65 |
| Juniors (41) | | | | | | | | | |
| XXI-A | | 1 | 2 | 4 | | | | 7 | |
| XXI-B, 1 | 1 | 1 | 5 | 1 | 1 | 3 | | 12 | |
| XXI-B, 2 | 1 | 4 | 14 | 2 | | | 1 | 22 | |
| | | | | | | | | | 41 |
| Sophomores (26) | | | | | | | | | |
| XXI-A | | | 1 | 1 | 1 | | | 3 | |
| XXI-B, 1 | | 1 | 6 | | 1 | 3 | | 11 | |
| XXI-B, 2 | 3 | | 6 | 3 | | | | 12 | |
| | | | | | | | | | 26 |
| | | | | | | | | | 132 |

The combined Psychology, Engineering and Humanities Program in Course XXI-A or XXI-B, 1 has been in operation for eight years and has been chosen by an average of ten to twelve students per year. This year it has come into first place as a choice, followed by Electrical Engineering. Over several years Mathematics, Life Sciences, Physics, and Electrical Engineering have held the first four places in varying order. The choices for the current third and fourth year students follow: Psychology -- 14; Electrical Engineering -- 9; Life Sciences -- 7; Physics -- 7; Aeronautical Engineering -- 4; Mathematics -- 3; Geology -- 2; Mechanical Engineering -- 1; Metallurgy -- 1; Major Departures -- 4. Of the four major departures two were in Education, and one each in Linguistics and Oriental Studies, the latter in combination with Harvard University.

Again this year the number of students enrolled in the XXI-B, 2 Program has exceeded the numbers in XXI-A and XXI-B, 1 (70-62; in 1970-71, 102-83). The movement towards concentration in a humanities discipline in the third and fourth year and away from a balanced curriculum of humanities and engineering or science may reflect a growing professionalism in the study of humanities at M.I.T., but it is interesting to note that a majority of students use their elective time in both programs for subjects in science, engineering, and social sciences and technical projects in order to be prepared for dual opportunities in future employment or study.

A new program in Anthropology began in fall 1971-72 with an enrollment of nine students. Social Inquiry, an experimental program instituted in the fall of 1969, has registered ten students. These two programs have both extended the range of Course XXI and offered new electives to all undergraduates. Fewer students in Course XXI elected Independent Activities Program in January, 1972, for credit (25 in 1971, 7 in 1972), but there was both an increase in non-credit participation and in programs of study offered by the faculty of the Department of Humanities.

Two requirements of Course XXI-A and XXI-B, 1 in the senior year are the Senior Humanities Seminar and the Thesis (History and Music require a thesis in B, 2 as well.) This

year the Senior Seminar began a second year study of Art and Community, bringing a dozen Boston artists, composers, and writers to the classrooms, using films, demonstrations, and the facilities of the Hayden Gallery for study under the direction of Professors Guggenheim and Lamson. Next year The Senior Seminar will return to a previous pattern of interdisciplinary study by offering with the Department of Aeronautics and Astronautics and several members of the departments of Engineering, Science, and Humanities a seminar in Technology, Power and Values. It is a happy note to report that the majority of theses submitted this year has been of very high accomplishment.

Of the eight Robert Boit Writing Prizes awarded in 1971-72, five were presented to Course XXI students, Phillip Bertoni, William Russell, seniors; Timothy Sammons, Seth Schneidman, juniors; Seth Racusen, sophomore. William Russell was a recipient of the Robert A. Boit Manuscript Prize. Three members of Course XXI were elected to Phi Beta Kappa, Jane Matrisciano, Kenneth N. Musen, Hadley M. Smith.

ROY LAMSON

## Music Section

This year saw the introduction of a subject in Non-Western Music (21.883). The major event for the students in the subject was the residency at M.I.T. of the P'ansori troupe from Korea from March 2 to March 19. The traditional musicians in this troupe rank among the finest in Korea. Individual lessons were given to students by members of the troupe at the M.I.T. Guest House. Lesson tapes and copies of the teachers' notes were made for use after the departure of the musicians. Tapes of important and rare categories of Korean music performed by the troupe were made for archival purposes. Extensive filming of the troupe was undertaken by students of film at M.I.T. The musicians were also actively involved with the local Korean community in celebrating a national holiday. An introductory lecture on Korean music was given by Professor Donald Sur, the instructor of the subject, with assistance from the musicians for the Boston community at the Museum of Fine Arts. Finally the various events were suitably climaxed with a concert at Kresge Auditorium on March 17. Other guests and participants of 21.883 include: Douglas Mitchell (Navaho music); Rulan Chao Pian (Chinese music); Robert Provine (historical aspects of Korean music); and Charles Seeger. A concert of works by students of the composition subject of Professor Sur was given in May.

Professor Barry Vercoe taught a new subject, Electronic Music Composition, to a group of students equally divided between music majors and students of Electrical Engineering. The Studio for Experimental Music, now located in Building 26-068, continues to grow and to attract attention within and outside of M.I.T. Professors Sur and Vercoe completed compositions and had them performed or recorded.

Professor Robert Freeman introduced a new subject on J.S. Bach and directed the M.I.T. Symphony Orchestra during Professor David Epstein's sabbatical. In addition, Professor Freeman participated as pianist in many informal and formal chamber music concerts, the other participants varying all the way from M.I.T. students to a member of the Boston Symphony Orchestra Cello Section, Mr. Luis Leguia. Professor Freeman was also called by the Music Department of Harvard University to take over its graduate seminar on baroque music during the spring term of 1972.

Professor John Harbison, who is the recipient of a 1972 National Institute of Arts and Letters Award for Musical Composition, was on leave of absence (on an Old Dominion Fellowship) during the spring term. During the fall, he took over the late Gregory Tucker's subject on 20th Century Music, and held a seminar on composition. In addition, he conducted the Cantata Singers and had several of his compositions performed in New York and Cambridge.

Professor John Buttrick, elected by the Music Faculty to be the Chairman of the Music Section for the coming two years, had another successful concert tour as soloist with orchestras and recitalist in Austria, Switzerland, and Germany. He also appeared twice as soloist with the Boston Pops Orchestra and at the Gardner Museum.

John Oliver, Conductor of the Tanglewood Chorus of the Boston Symphony Orchestra, joined the faculty as conductor of the Glee Club and Instructor in Music. Next year Mr. Oliver will take over the conductorship of the M.I.T. Choral Society, as well.

The student musical organizations had another very active year. There were tours by the Concert Band (John Corley, Director), the Symphony Orchestra, the Logarhythms, and the Jazz Band (Herb Pomeroy, Conductor), and there were visits to and by Smith College and Mt. Holyoke College Glee Clubs. Probably most gratifying and noteworthy were several occasions when M.I.T.'s musical organizations combined -- during the Inaugural Festivities of President Wiesner; during the Spring Festival of Music; and during I.A.P. Perhaps one could take the music program of I.A.P. as a sample for the interrelatedness of the specialist and the general public, the professional and the amateur which is possible when it comes to music. An enumeration of the I.A.P. subjects offered will suffice: "Quartertones;" "Relationships between Analysis and Performance;" "Lecture demonstration on 'Five Settings,' a choral work by John Harbison;" "Brahms' German Requiem, preparation of an informal performance in combination with lectures on this work -- M.I.T. Choral Society, Symphony Orchestra, guest soloists, Klaus Liepmann, Conductor;" "Jazz, a Workshop on Arranging;" "Humor in Music" -- Professor Freeman; "Songwriting."

There were entirely too many concerts during the year to enumerate them all. Suffice it to say that twenty-one library concerts (arranged by Professors Buttrick and Freeman), and weekly noonhour concerts at the Chapel (arranged by the Institute Organist, Mr. John Cook) were attended throughout by a capacity audience.

The Humanities Series, which Professor Tucker had organized and guided for so many years, continued as "Chamber Music at M.I.T." with a somewhat expanded and greatly varied program. Soloists were Eric Rosenblith, Violinist, and Dik Visser, classical and Flamenco guitarist and composer from Holland. Furthermore, in collaboration with the Goethe Institute, the Music Faculty of M.I.T. presented the noted German composer Stockhausen with his "STIMMUNG." A group of young American musicians, the Da Capo Chamber Players presented a program of American contemporary music. And finally, a Schubert Festival took place, presenting in two concerts the two famous Schubert Cycles: "Die Schone Mullerin" and "Winterreise." The artists were Leslie Guinn, Baritone, with John Buttrick, and Ernst Haefliger, Tenor, with Franz Rupp.

In closing this, the last yearly report of the retiring chairman of the Music Section, a personal note may be in order. It has been a joyful and stimulating experience to have had a hand in the creation and development of a music program at M.I.T. The keen interest of the students, their abundance of curiosity and talent, an understanding, wise, and most congenial administration, and a brilliant music faculty, all have made it thus. No doubt, within another 25 years more space and facilities for the ever-expanding program will have been found.

The most important aspect, and one never to be lost, seems to be the interaction of professional and amateur performers and audience, scientist and engineer, creative and performing artist. Science, Engineering, and the Arts need to cooperate in an all-around dedication to one of the least devalued and counterfeited emanations of the human spirit.

KLAUS LIEPMANN

# Department of Philosophy

As predicted in last year's report of the Department of Humanities, the change from sectional to departmental status for Philosophy has been largely an organizational one, involving no significant changes in educational programs or scholarly efforts. The Department continues to participate heavily in the teaching of freshman and sophomore "core" subjects, the undergraduate major in philosophy remains essentially unchanged, the graduate program operates at substantially the same level as before, and research activities proceed in areas in which the Department already enjoys distinction.

## Teaching Activities

Approximately 55 percent of the Department's teaching time is spent in freshman and sophomore subjects. Enrollment in Contemporary Moral Issues, 24.01-.02, an option available for satisfaction of the freshman requirement in humanities and social sciences, remains high: 244 first term and 263 second term. Philosophy: Classic and Contemporary, 24.11, the Department's entry in the options available for satisfaction of the sophomore requirement in humanities and social sciences, drew 165 first term and 91 second term. Although the Department intends to remain heavily involved in the teaching of freshmen and sophomores, we hope for diversification of subject offerings, especially at the freshman level. Besides giving freshmen a biased view of the Department's activities, the present arrangement leads to staffing problems that increase in severity as the years go on.

The program leading to the degree of Bachelor of Science in Philosophy, in which 15 students have been enrolled this year, is a slightly modified version of that offered under the auspices of Course XXI-B, Program 2. Over and above General Institute Requirements, students in the program are required to complete 54 units of restricted electives, of which 18 must be in Philosophy and 36 in advanced subjects in some other discipline. The program is intended to provide familiarity with the history and current status of the central problems of philosophy, mastery of some of the technical skills requisite for advanced work, facility at independent study, and work at an advanced level in an allied field. It is designed not only for students who anticipate careers in philosophy but also for students who seek perspective on a scientific education or who wish breadth of educational experience prior to entering professional programs.

In spite of shrinking fellowship funds and a poor job market, the graduate program has suffered only a small diminution in size and no diminution whatever in quality. The Department competes well for new students, especially in those fields such as philosophy of logic and language in which it has a national reputation, and so far problems of placement have not been severe. Two doctorates were awarded this year, bringing to 11 the total number awarded since the inception of the program in 1964. Much of the success of the program must be credited to Professor Sylvain Bromberger, who has served ably and energetically as Chairman of the Department's Committee on Graduate Students.

It is difficult, however, to be optimistic about the future of the graduate program. If financial support for graduate students continues to decline, the Department will be unable to compete with public institutions at which tuition charges are minimal. Even the most dedicated students are reluctant to incur heavy indebtedness in preparation for a career that is at best only moderately lucrative.

## Research Activities

Research by members of the Department covers a wide spectrum ranging from such topical issues in normative ethics as abortion (Professor Judith Thomson and Baruch Brody) to such esoteric matters as a generalized notion of omega-consistency (Professor George Boolos).

This year Professor Jerrold Katz published two books in generative semantics: Semantic Theory and The Underlying Reality of Language and its Philosophical Import. Professors Jerry Fodor and Ned Block collaborated in work on the nature of psychological states and on the distinction between analog and digital computers. Professor Block is also working collaboratively with Professor Gerald Dworkin on the current controversy over alleged genetic determinants of intelligence. Professor Huston Smith contributed to the National Geographic Society's volume entitled Great Religions of the World.

### Personnel

Three members of the Department will enjoy leaves of absence next year. Professors Fodor and Katz have been awarded Guggenheim Fellowships and will be on leave for the entire year. Professor Boolos will spend the second term on an Old Dominion Fellowship. Professor David Levin is leaving M.I.T. to accept a position at Northwestern University. David Smith, currently on the faculty of Indiana University, will join the Department as assistant professor in September. He is a specialist in the philosophy of Husserl and will offer subjects in the areas of phenomenology and existentialism. Miles Morgan, currently finishing his doctorate in government at Harvard, will also join the Department in September. His subjects in political philosophy will strengthen the Department's ties with the Department of Political Science.

RICHARD L. CARTWRIGHT

## Department of Political Science

The Department has devoted a substantial share of its energies this past year to the undergraduate program, partly out of a concern at a decline over the past two years in undergraduate majors and course enrollments. The drop may have to do primarily with competition from the new undergraduate program in Urban Studies, or it may stem from less obvious changes in patterns of undergraduate interests; whatever the causes, we are seeking ways to bring the Department more strongly to the attention of the undergraduate body.

One step taken this year has been to plan two new subjects for freshmen, one on the political aspects of modernization in the less-developed countries, the other on problems of industrial societies and changes in them since the Industrial Revolution. We hope that by offering these subjects as one of the Freshman Humanities options, and by having a substantial portion of the senior faculty teach them, we can begin to make undergraduates more aware at an early stage of their M.I.T. careers of what Political Science has to offer. A second change to be introduced next fall is a revised undergraduate advisory system. The present arrangement, in which virtually all faculty members participate, has too often been characterized by only perfunctory contacts and has not effectively served to encourage student-faculty interaction. The new system, which was employed on a experimental basis this year with our sophomore majors, will rely on a smaller team of undergraduate advisors who will supplement the usual advisory activities with informal seminars and other appropriate encounters, often at faculty homes. Faculty members not serving as advisors will be asked to step up their involvement in freshman seminars, the undergraduate research opportunities program, and other activities that bring them into personal contact with undergraduates and increase the Department's "presence" in Institute affairs.

The Department is similarly attempting to increase somewhat the number of graduate students enrolled, in the belief that we can handle more students without sacrificing our comparative advantage of small classes and a high level of personal interaction between faculty and student body. We have accordingly admitted a larger group of graduate students than before, conscious that certain potential risks and costs may be involved. Since no new sources of fellowship funds have been uncovered, students will be less certain than in the past of receiving help from the Department, even when they are performing well. We count on

closing the gap by relying more heavily on research grants to provide assistantships. A second risk has to do with the shrinking academic job market. Although virtually all our graduates have again this year managed to find suitable employment, or post-doctoral fellowships, it is clear that the traditional automatic expectation of locating a teaching position in a good political science department is a thing of the past. We will have to help create different sets of job expectations and will want to reorient some aspects of our graduate training program accordingly.

The faculty intensified their efforts this year to develop new research directions and sources of research support. The increased developmental effort was necessary because of the relative scarcity of research funds, especially in the international area, and the drying up of fellowship funds. The Department has of course always been research-oriented so that the change has been one of degree only.

Considerable attention has been placed on developing projects that cut across several fields within the Department and on research areas that could be developed collaboratively with faculty in other social science disciplines or in the sciences and engineering at M. I. T. Some of the more important new directions are projects concerned with comparative studies of advanced industrial societies, comparative urbanization studies in developed and developing societies, rural-urban migration studies, research built around the new technology of cable television, and a major new program in cooperation with Harvard on the international implications of technology. These general research areas and a host of other more narrowly defined subjects were the focus of planning and research for many of the faculty over the year. Several of the research proposals that resulted were successful; others are presently under consideration by foundations and government agencies.

In general, it can be said that the research funding picture, which looked so bleak a year ago, has begun to turn around. That does not, of course, mean that all problems are solved, for it has continued to prove difficult to raise adequate funds for students and for secretarial assistance and other administrative overhead. In addition, it has proven particularly difficult to raise flexible funds to assist in developing new research areas and to help projects get started. By and large, many of the new funding sources are interested only in detailed and fully developed research projects, often demanding high policy relevance for support. In time, these kinds of constraints from funding sources may prove to create major problems for the development of the field.

During the year, the Chairman of the Department, Professor Eugene B. Skolnikoff, also became Director of the Center for International Studies. This appointment reflected the desire to move the Center in new directions toward closer collaboration among the hard and soft sciences at the Institute. The new research directions in the Center, largely to be concerned with the international political, economic and social aspects of technology and technological development, will inevitably affect the Department of Political Science as well, by increasing opportunities for multidisciplinary work on international issues related to technological change.

Three new faculty members have been appointed for the coming year after an intensive search and screening of a large number of candidates. Dr. Hugh Heclo, now at the University of Essex, has been appointed Assistant Professor and will teach subjects in public policy analysis and in his special field of comparative social policy. Two young black scholars have been named Instructors in the Department: Lorenzo Morris, now completing his Ph. D. at the University of Chicago, specializes in urban studies and in black studies; and Michael J. Mitchell, working on his Ph. D. at Indiana University, is a student of Latin American urban politics. An appointment as Research Associate has also been given to E. Lovell Dyett, formerly of Howard University, to conduct research on the urban use of cable television.

Recruitment efforts will continue in the coming year. First priority will be given to an additional appointment in urban affairs, hopefully a senior appointment jointly with the Department of Urban Studies and Planning. Our most pressing additional need is for a junior person in American Government and Public Law, fields in which the Department is distinctly understaffed to meet student demand.

Space does not permit reporting on the individual research and other professional activities of members of the Department. Let it simply be recorded that five books and over 50 articles and chapters were published this year by members of the faculty and that the faculty continued to be actively engaged as consultants to government agencies, participants in the affairs of professional organizations, and contributors to various Institute committees and ad hoc groups.

Associate Professor Jack Saloma, who has made a major contribution to the Department through his research and teaching in American politics and his concern for our undergraduate program is leaving the Department at the end of his appointment. Returning to their home universities are two Visiting Professors who joined us for the academic year, Professor Frans Alting Von Geusau from the University of Eindhoven in the Netherlands, who taught subjects in international relations, and Professor Louis Guttman, a distinguished social scientist from the Hebrew University, Israel. Two senior part-time Visiting Professors assisted the Department with special subjects during the year -- Emilio Q. Daddario, former member of Congress from Connecticut and Bruce L. R. Smith, Professor of Government at Columbia University.

EUGENE B. SKOLNIKOFF

## Department of Psychology

Members of the Department of Psychology have continued their teaching, research, and participation in Institute affairs supported by the largest budget of the Department's brief (eight-year) history. This ever-growing level of external support attests to the vitality of the enterprise. We appear to be in an era which increasingly recognizes the actual and expected contributions to science and health that can be made by combining the resources of behavior study with those of research on the brain. Since the Acting Chairman is writing this review, he may, without loss of modesty, attribute the Department's success in no small measure to the imagination and energy of its Chairman, Hans-Lukas Teuber, presently on partial loan to Oxford University.

Along with growth of facilities and personnel come the inevitable problems of housing and of securing additional long-term support. To relieve the internal pressure on space, we have taken over part of an adjacent building (E-20) and are in the midst of plans to refurbish that building for housing essential animal and laboratory facilities. Transforming these plans into reality has been made possible, in part, by an unusual subvention from the Grant Foundation in New York, providing us with backing for permanent installations. Such funds are extremely hard to come by; this award, from a farsighted foundation, can be taken as a vote of confidence, both in the areas of investigation contemplated and in the personnel who will carry out the work. Along with these building funds, the Grant Foundation has donated fluid funds for a period of four years to help support our efforts in studies of early development of behavior, in relation to the nervous system.

Maintenance of present levels of support for ongoing activities remain a rather more difficult problem. Although our faculty and staff have shown themselves capable of preserving and even increasing their individual levels of support from reduced Federal sources, funds for initiating and continuing innovative programs are scarce. The Sloan Foundation grant has launched our new program leading to the combined Bachelor's and Master's degree in Neural

Sciences in Relation to Behavior, but the continuing success of this program will depend upon our efforts at turning up further sources of general funds, a task to which we must devote ourselves in the coming year.

## Teaching

The departmental teaching activities cannot be reviewed without stressing the one atypical feature of the year. For parts of both terms, Professor Teuber was George Eastman Visiting Professor at the University of Oxford where he gave the 32 lectures and seminars stipulated under the terms of that professorship, and thus was unavailable for his usual share in the undergraduate instruction at the Institute. It was to be foreseen that his absence would lead to a temporary downturn in undergraduate enrollment. That this downturn was not greater than it was is due to the devotion of those who were put into the difficult position of pinch-hitting for an unusually popular lecturer-Professor Hein for the introductory subject (9.00) and Dr. R. Smith for the intermediate subject in learning (9.40). For the coming year, with everyone back on board, we expect to return to the previous high levels of undergraduate enrollment in the department's introductory and intermediate offerings, all of which remain electives.

On the graduate level, the trends were quite different. Here, a faculty of 11 instructed the largest number of graduate students thus far (altogether 252 over the two terms, as compared with 119, 236 and 216, respectively, in the three immediately preceding years). The number of regular doctoral students rose to 25. The majority of these students continue to be supported by the departmental training grant from the National Institute of General Medical Sciences. The renewal of this grant for yet another five-year period, without significant reduction in funding, was a particularly welcome event during the period under review.

Among several new topics covered in the departmental teaching program, we should mention a one-term survey of behavior genetics which was taught at the advanced undergraduate level in the spring term by Dr. Ruth Guttman, who came as a visiting professor from Israel. On the graduate level, the signal event of the teaching year was an extremely active staff seminar on vision, its neural basis and development, taught jointly, twice a week, by five faculty members and research staff, and catalyzed by the presence, for the fall term, of Dr. Colin Blakemore from the Physiology Department in Cambridge, England.

In fact, yet another way of characterizing the year just past is to call it the most international year in the departmental history. By last count, altogether 19 visiting investigators and visiting faculty came to the department from nine different countries overseas, and spent from one week to a full year in the departmental laboratories. In turn, our faculty was involved more than ever before in various international meetings, beginning with the Congress of Physiological Sciences in Munich in the summer of 1971, and its various "satellite" symposia (Professors Bizzi, Nauta, Schiller, Schneider and Teuber), and continuing early in 1972 with the U.S.-Australian Symposium on Vision in Canberra to which Professor Peter Schiller and Dr. Ann Graybiel went as invited delegates from the Department. In June, 1972, Professors Nauta and Teuber were invited participants at the International Neuropsychology Symposium in Aix-en-Provence.

The international representation was equally strong in the departmental colloquium program which exceeded all previous years in the number of speakers; there were 65 colloquia with 21 of the speakers coming from abroad.

Within the Institute, the departmental faculty further increased its participation in various interdepartmental ventures and programs and many served many hours on Institute committees. Professor Held, besides being Acting Department Head during Professor Teuber's temporary absence, took an active role in the development of plans for the proposed Division

on Education. He and Associate Professor Mary Potter served on the Faculty committee for the joint Harvard-M.I.T. Program in the Health Sciences and Technology, while Professor Nauta and Professor Chorover worked on behalf of the same program, on its curriculum committee (Nauta) and on its committee on undergraduate teaching in human biology (Chorover). In addition, Professor Nauta began the development of a new introductory subject in the neural sciences to be offered next year within the Harvard-M.I.T. Program, jointly with Professor Paley and others of the Harvard Medical School, and with Professors Bizzi, Graybiel and Kasten in our own Department. Professor Nauta also continues his service on the Institute-wide Committee on the Use of Humans as Experimental Subjects and on the Animal Care Panel. Professor Hein, besides filling the gap in teaching left by Professor Teuber's absence, served as Chairman of the Institute Committee for Pre-Professional Advising and Education, and as co-chairman of an ad hoc committee to evaluate the effects of freshmen pass-fail arrangements on admission to medical school. Professor Richards continued to serve on the Committee on Graduate School Policy where he was chairman of the subcommittee on graduate instruction.

Professor Teuber, who actually divided his time between Oxford and M.I.T. (spending an aggregate of six months out of the twelve in 1971-72 in each of the two institutions) continued to serve on the Institute Standing Commission for the Special Laboratories, and on the Clinical Research Center Board. He also served as member of the Scientific Advisory Committee of the Massachusetts General Hospital.

Recognition and calls from outside sources came to faculty members in various other ways. Professor Held was elected to the Society of Experimental Psychologists and Professor Richards became a Fellow of the American Optical Society. Professor Held also continued as member of the National Research Council Vision Committee, while Professor Nauta was elected President of the Neurosciences Society and, simultaneously, a member of the Executive Board of the American Association of Anatomists. Professor Fodor received a Guggenheim fellowship for 1972-73, and Professor Garrett served as a member of the Fellowship Review Board of the National Institute of Mental Health. That same Institute continued to rely on advice from other members of our small faculty; Professor Nauta remained a member of their Board of Scientific Councillors and Professor Chorover, besides his service on the Neuropsychology Study Section, was called to join the newly established Task Force on Research in Mental Health. Professor Teuber, during his tenure of the Eastman Professorship at Oxford, received the Craik Award in Experimental Psychology from St. Johns College at Cambridge University, and became a member of the U.S. National Academy of Sciences, which had already elected Professor Nauta several years ago.

It remains for us to record at least some of the comings and goings among departmental staff, and to report on promotions. It is our happy duty to announce that Associate Professors Bizzi, Hein and Richards all achieved full professorial rank at the end of the review period. Less happily, but also with some pride, we must record that Dr. Lennart Heimer, who had come to Professor Nauta's laboratory six years ago as a postdoctoral fellow from Sweden and stayed on as a research associate, was offered, and accepted, a chair at the University of Virginia Medical School. His work will be remembered for its beautiful contributions to the staining of nerve tissues, through elaborations of Professor Nauta's famous stain, and for the applications of these new methods to problems of neural connections, especially in the olfactory system.

On the other hand, we can record one addition to our teaching faculty. As of this fall (1972), Dr. Susan Carey-Block will join us as Assistant Professor in Developmental Psychology; her main interests concern the early development of perception and logic in children. Furthermore, Dr. Mary Potter, whose time as an associate professor had been shared between the Department of Urban Studies and Planning and our department, will begin to devote three-quarters of her time to our department, without severing her connections with Urban Studies

and Planning. Her teaching will continue to focus on social psychology.

## Epilogue

It will be apparent from what has gone before that our department operates much like an interdisciplinary center, with its commitment to the three interrelated areas of brain and behavior, perception and learning, and early development, including psycholinguistics. The departmental teaching flows quite directly out of its investigative activities and these activities profit in turn from the presence of the various overlapping teaching and training programs. At the same time the interaction with other departments and centers around the Institute continues to grow, and much of this new collaboration will be reflected in several specific interdepartmental ventures in the coming year. That year -- the ninth since the department was founded -- will be at least as active as any of the previous years, and should see an even greater coalescence of the different fields in which our faculty has elected to do their work.

RICHARD HELD

# Alfred P. Sloan School of Management

In the 20 years since its founding, the Sloan School of Management not only has moved into the first rank of schools of business and management in this country but also has come to be recognized as an important source of innovation.

Its early decision to base its curriculum and educational strategy on the assumption that basic and applied research could contribute important new concepts and ideas to the practice of management represented an important departure from the strategy underlying schools of business and management up to that time. It is now clear that the early decision to proceed along these lines was sound, and now the strategy which has guided the Sloan School for the past 20 years is rapidly being undertaken by other schools around the world.

In executive education the Sloan Fellows Program, which preceded the formal establishment of the School, was in its conception the most imaginative and serious attempt to deal with the transition from functional to general management for the mid-career executive, and the program today remains the standard by which quality in executive development programs is measured.

Shorter executive development programs aimed more specifically at the transfer of modern techniques in areas of specialized concern grew enormously in popularity and effectiveness during the 1960s. The Sloan School contributed substantially to that process.

The Sloan School's basic commitment to quality in its faculty and the programs which they design permitted it to recruit faculty from many disciplines for the purpose of institutional development during the 1960s. Its contributions to the Indian Institute of Management in Calcutta, along with those of the Government of India, the State of West Bengal, and the Ford Foundation, have resulted in a viable and badly needed management research and education capability under the most difficult economic, social, and political conditions. The development process which the Sloan School demonstrated in this undertaking has been followed by other schools not only in Asia but in Europe, Africa, and Latin America.

Faculty development was one of the basic problems which schools wishing to move toward a Sloan School model faced during the late 1950s and early 1960s. Early attempts to grapple with this problem in cooperation with the Sloan Foundation in the form of a teaching internship program evolved into a new style doctoral program in the early 1960s, which has turned out not only to be viable and effective at M.I.T. but at other universities as well.

During the middle 1960s important management problems in the fields of health, education, and urban and public affairs led the School to become one of the first of the major schools of management to include a concern for these problems in its programs of teaching and research. Over the years since that time other schools have come to see the promise of combining concern for private and public management problems and are moving to undertake directions of development which the Sloan School pioneered.

A year ago the Sloan School announced an Accelerated Graduate Program designed to take advantage of curriculum development which had resulted from its investments over the previous three years. This program, which is concerned first with the quality education of

its students is also concerned with increasing the productivity of the educational experiences of the students who participate in it, the faculty who teach, and the facilities in which the program is conducted. It now appears that all these objectives have been accomplished at least for the first class, and there is every reason to be optimistic with respect to the future of this new idea. Other schools are already considering this model, and it would appear that needs not normally associated with general management education, such as the preparation of much needed professionals in the health profession, can also usefully be served by this new curriculum design.

To a considerable extent, all of these developments grew out of the School's basic strategy of pursuing pure and applied research as a basis for its educational programs. It is proud of the achievements attained under this strategy and the body of this report summarizes the Sloan School's activities in teaching, research, and other School programs for the academic year 1971-72.

## Teaching Programs

### Undergraduate Program

Approximately 150 students were enrolled in the undergraduate management program and over 600 M.I.T. students elected management subjects as part of their program of study.

Managerial Psychology, one of the five core subjects, was revised to include laboratory and project exercises and is now included among those subjects which may be taken to satisfy the General Institute Laboratory requirement. The opportunity to fulfill the Institute Laboratory requirement by working in an area of management studies adds strength to the undergraduate program at the Sloan School. Substantial revisions were also made in another of the core subjects, Managerial Environment, which was taught this year by Stanley M. Jacks, Senior Lecturer.

There were no changes in the faculty advisors for the four constituent programs of study for undergraduates: Professor Jay R. Galbraith -- Special Program; Professor Thomas J. Allen -- Behavioral Science; Professor Paul R. Kleindorfer -- Management Science; and Professor John Henize -- Dynamics of Management Systems. Professor Myron S. Scholes served as advisor for the few students still enrolled in the General Management Option, which was phased out in June, 1972. During the coming year, while Professors Galbraith and Kleindorfer are on leave, Professor David N. Ness will serve as advisor for the Special Program students, and Professor Thomas L. Magnanti will advise students following the Management Science program. The basic structure of the present undergraduate management program, introduced five years ago, has served well both the needs of students and the goals of the faculty. Nevertheless, the rapid development of management science and the increasing interest throughout the Institute in the application of this knowledge to the solution of diverse problems requires that the design of undergraduate management education, like all Sloan School programs, be reexamined periodically. The School plans in the coming year to undertake such a broad review.

### Master's Program

Graduate work in management at the School is distinguished by its emphasis upon the fundamental disciplines underlying managerial decision making and by its search for an integrating theoretical framework for the study of management. First, there is emphasis on the study of man himself -- the whole range of organizational relationships among men, groups, and the environment in which they carry out their activities. Second, the School stresses quantitative analysis of management problems, applying the methods of science to the complex interrelated elements of the enterprise. Finally, in the functional fields,

theory is applied to practical problems which arise constantly in the world of action.

Although the majority of Sloan School students in the past have aimed at careers in business and industry, a growing interest is observed in the management of other institutions of great concern to society: hospitals, schools, cities, and government agencies. At the same time there is an increasingly pressing need for better managers of all types of organizations. The basic approaches to problem solving and decision making developed for industry are applicable to non industrial organizations. The School encourages applications from those who seek careers in a wide range of enterprises.

In addition to fulfilling specific core requirements, each student must choose one elective which exposes him to broader problems of the relationship of managers with government and society. Among the various alternatives, students most frequently elect such subjects as American Legal Systems, International Business Environments, Private Industry and Environmental Problems, and Studies in Public Operations Management. It is common for students to elect more than one such subject.

The School's membership in the Council of Opportunity for Graduate Management Education (COGME) brings it applications from minority students who might not otherwise consider applying to the Sloan School. It relies also on its present minority students to help it recruit new applicants.

Considerable faculty time and effort have been invested this past year in the planning and inauguration of a new program designed to fill two needs: the need of M.I.T. to use facilities idle in the summer months, and the need of persons already employed to minimize the loss of time necessary to obtain management education. A carefully selected group of 32 students entered the new Accelerated Graduate Program on June 5, 1972. New developments in curriculum design and pedagogical method are intended to help these students complete seven of the eight core subjects during the summer term. An extra load of one subject per term in the fall and spring terms will permit satisfaction of degree requirements in one calendar year.

A total of 112 S.M. degrees were granted in 1971-72. The median starting salary of Sloan School Master's Program graduates in 1971 continued at approximately $1,250 per month. Twenty-seven percent of these alumni obtained employment in banking and other financial organizations; 18 percent in consulting; 16 percent in nonprofit (government, military, education) organizations; 8 percent in petroleum and chemicals; 7 percent in computers and high technology; 6 percent in automotive and heavy industry; 18 percent in other types of organizations.

## Doctoral Program

The new program design instituted in September, 1969, has been in effect for the generation of students who completed their work for the Ph.D. degree in 1972. The number of well-qualified applicants has increased, and graduates have found good positions in spite of a general looseness in the academic labor market.

Several features of the program have been warmly endorsed by both students and faculty: 1) the flexibility afforded by the absence of any rigid course requirements has permitted students to design individualized programs with faculty guidance and approval; 2) the expectation that students will be active in research during their first and second years has provided improved preparation for their doctoral dissertation; and 3) the opportunity to share some teaching experience with a member of the faculty has provided a valued learning situation.

The most critical problem for the next year and the future is the drastic reduction in

fellowship support by Federal and other external sources. The Committee for the Doctoral Program believes strongly that Ph. D. candidates should be supported financially because their earnings in careers in research and teaching will not justify heavy debts and because part-time jobs seriously interfere with their scholarly activity and academic progress. The funds available to the Sloan School, however, are currently inadequate for this purpose and it must continue to seek alternate sources of financial support for doctoral candidates.

Ten Ph. D. degrees were awarded during the year. Seven of the Ph. D. recipients went into teaching at the following schools: Boston University, Harvard University, San Diego State College, Stanford University, Tel Aviv University, University of British Columbia, and the University of Western Ontario. Other Ph. D. graduates accepted positions at: Lang Engineering, Societé Nationale des Petroles d'Aquitaine, and Systems Research Group.

## Alfred P. Sloan Fellows Program

The thirty-fourth class of Alfred P. Sloan Fellows graduated on June 2, 1972, receiving the Master of Science in Management. The Class of 1972 began its year of study on June 18, 1971. There were 45 in the class, and they represented the most varied backgrounds of any class in the program's 40-year history. The average age of the Fellows was 35.6 years. Three Fellows came with other M. I. T. degrees; 17 came with Master's degrees; one came with a Ph. D. degree; one with an M. D.; and one with a J. D. degree. Eighteen Fellows represented U. S. industry; 8 -- foreign industry; 10 -- U. S. government; 2 -- foreign government; 2 -- urban government; 1 -- United Nations; 1 -- military; 1 -- medicine; 1 -- clergy; and 1 -- research institute. Countries represented by the Sloan Fellows and their organizations included Canada, France, Ghana, Great Britain, Japan, the Netherlands, Trinidad and Tobago, and the United States.

A number of organizations were represented for the first time: Agency for International Development; Battelle Development Corporation; Berol Corporation; British Foreign Office; C.A. Energia Electrica de Venezuela; Cambridge Information Systems, Inc.; The Dai-Ichi Kangyo Bank, Limited; Delta Brassfoundry Ltd.; New York City Housing and Development Administration; New York Urban Coalition; Nippon Electric Company, Japan; Philips' Industries, the Netherlands; St. John's Abbey; Trinidad-Tobago Industrial Development Corporation; United Nations; U. S. Atomic Energy Commission; University of Rochester School of Medicine; and Rochester General Hospital.

Recruiting for the Sloan Fellows Program has been more difficult over the past two years, but efforts have been well rewarded. In a period of almost universal belt tightening, the number and quality of applications for what many regard as a long and expensive program have held up remarkably well. Recruiting may continue to take more time and energy until the economy is stronger than it is at present. The single most effective recruiting strategy will be the positive assessment of the program by the Sloan Fellows at the end of their year here.

Professor Charles A. Myers, Sloan Fellows Professor of Management, continues as chairman of the Program Evaluation Committee. Professor Myers and his committee maintain a close relationship with the Sloan Fellows throughout the year, and all benefit from the wisdom and warmth with which Professor Myers and the committee respond to the needs of this unique program.

## M.I.T. Program for Senior Executives

The thirty-second and thirty-third programs were offered in 1971-72. Demand continues strong both from within the United States and from countries from throughout the world. The wide variety of national backgrounds represented in the program is impressive. In keeping with the international character of the program, the curriculum offers an increasing

number of topics and seminars of interest to multi-national executives. The variety of backgrounds and nationalities in the program is one of the important strengths of the program. The conducting of informal seminars by senior executives for other students at the Sloan School was an important new feature of the 1971-72 program.

The program committee has sought to develop opportunities for the seniors to meet with more faculty members, to pursue their individual interests, and to determine greater portions of their activities within the framework of the resources available to the program at the School. The seniors select their own luncheon and dinner speakers, some of the seminar leaders, and they use some free time made available to them to fulfill their own learning objectives.

Professor Zenon S. Zannetos completed his third and last year as chairman of the faculty committee. Professor Zannetos contributed in important ways toward the design and coordination of the curriculum and his support counted heavily toward continuing to make this program one of the most respected of its kind in the world. The School welcomes Professor Michael S. Scott-Morton as the new chairman of the faculty committee and looks forward to his leadership of this important effort. The new director of the program is Robert Ilfeld who replaced Joseph M. Patten in August, 1971. Mr. Ilfeld is an M.I.T. alumnus (Class of 1944) and was a Sloan Fellow at M.I.T. in the Class of 1966-67.

The age range of senior executives in both the fall, 1971, and the spring, 1972, programs continued at the mid-thirties to mid-fifties with the average age in the mid-forties. Many of the senior executives come to this program with advanced degrees; there were 12 senior executives with master's degrees and 4 with doctorates in the spring, 1972, program. Typically, 10 to 12 foreign senior executives participate in classes whose enrollment generally ranges between 25 and 27 participants.

## M.I.T. Program for Urban Executives

The fourth M.I.T. Program for Urban Executives was held at Endicott House and the Sloan School from June 20 to July 16, 1971. Part of the teaching load was carried by faculty from the Department of Urban Studies and Planning and by guest lecturers from municipal and state government.

Eighteen participants from 15 cities attended the program. Participants were city managers, assistant city managers, department heads, and other career managers. The demand for places continues to grow. The fact that the fifth program, offered from June 4 to June 30, 1972, was fully subscribed was a further sign of this strong interest. One of the most encouraging phenomena is to be found in the fact that those cities that have been represented in earlier programs continue to make nominations.

This program continues to enjoy and appreciate the support of the following organizations: the National League of Cities, the United States Conference of Mayors, and the International City Managers Association. Mr. Ilfeld is the program manager for this effort as well as for the Senior Executive Program.

## Greater Boston Executive Program

The Greater Boston Executive Program was offered from January 28 to May 12, 1972. This marks the fifteenth year of this unique example of collaborative university-business community effort to develop managerial resources within the greater Boston area.

Twenty-five participants representing 16 organizations attended the program. The School was pleased to have two women among the participants, one from the Polaroid Corporation and one from the New England Telephone and Telegraph Company. Two members of minority groups also attended. The School hopes to see a continuing increase in the number of minority group

members and women in this and other programs. This year a special invitation was extended to an executive from the Roxbury branch of the greater Boston Y. M. C. A. He brought with him expertise concerning social problems of the city that was most welcome.

The program is still managed by a small group of business executives in the greater Boston area. They work on a voluntary basis and with great dedication to this small but important community effort.

## Summer Programs

Seven special programs for professional men and women in industry, government, and education were offered during the summer of 1971. Two of these were conducted as "live-in" programs held entirely at Endicott House. Each was of one week's duration and was presented by members of the Organizational Studies Group in the School.

*The Management of Human Resources*

This program was designed to present the leading edge of current research and practice on the management of human resources and to allow experience sharing among the participants. Professor Jay R. Galbraith coordinated the program, which featured sessions with Professors Mason Haire, Edgar H. Schein, Charles A. Myers, Irwin M. Rubin, Edward B. Roberts, and Donald G. Marquis, as well as Visiting Professor M. Scott Myers and Senior Lecturer Richard Beckhard.

*Human Effectiveness in Today's Organizations*

M. Scott Myers, Visiting Professor of Organizational Psychology and Management, designed this intensive one-week program for top-level executives and key staff personnel responsible for developing conditions for human effectiveness in organizations. The course discussed the relation of the work of Professor Clare W. Graves (Professor of Psychology at Union College) to other tested concepts of organizational development. Professor Graves spent two days with the program. Professors Myers and Schein conducted the remainder of the program.

The other five programs were conducted at the Sloan School.

*Industrial Dynamics: Corporate and Social Systems*

This program presented an intensive treatment of how organizational structure, policies, information flow, and time delay create fluctuation, growth, or decline, or maintain favorable or unfavorable equilibrium positions in corporate and social systems. Professor Carl Swanson directed the program; other participants were Professors Jay W. Forrester, Roberts, and Dennis Meadows, with Alexander L. Pugh III and other members of the Systems Dynamics Group in the School.

*Management of Research and Development*

Over its eight-year history, this program has developed the successful format which combines a variety of educational approaches to R&D management. It continues to be sought out by persons in government and industry who are responsible for directing research and development programs. Professors Edward B. Roberts and Donald G. Marquis directed the program. Professors Thomas J. Allen, George F. Farris, and Jay R. Galbraith collaborated in the problem oriented workshops and lecture discussion sessions.

*Management Science in Marketing*

Under the direction of Professors Philippe A. Naert and Alvin J. Silk, this two-week program emphasized the application of behavioral research and mathematical modeling techniques to marketing management problems. Existing models were surveyed and potential applications of management science to marketing were outlined. Professors John D. C. Little and Glen L. Urban and Dr. Arnold E. Amstutz also participated in the program.

*Models for Financial Management and Long-Range Financial Planning*

Professors Stewart C. Myers and Gerald A. Pogue offered this program designed for corporate financial staff, management, and consultants for the third consecutive year. The program presented an intensive examination of several of the most promising analytical approaches to financial problems, with special attention to the financial environment, decision-making criteria, and basic financial concepts. Guest lecturers included Professor Michael S. Scott-Morton and Robert F. Calman, Vice-President, International Utilities, Inc.

*Project Management: Organization and Planning Models*

This program introduced recent advances in project management techniques and integrated them with existing network based management information systems. The emphasis was on the development of operational planning and control systems. The program was under the direction of Professor Wallace B.S. Crowston. He was assisted by Professors Jay R. Galbraith, Warren H. Hausman, Paul R. Kleindorfer, and Guest Lecturer David Chapman, Director of Information Systems, Systems Manufacturing Division of International Business Machines.

*Industrial Liaison Office Symposia*

In addition to the summer program offerings, Sloan School faculty contributed to a number of Industrial Liaison Office programs and symposia. In November, Professor Forrester was chairman of a symposium on systems dynamics, and Professor Franco Modigliani was co-chairman with Professor Robert M. Solow of the Department of Economics of a symposium on econometric modeling and projections. Dean William F. Pounds served as chairman of two symposia, one in February on operations management and one in May entitled "Social Roles for Corporations."

## Research in the Sloan School

Traditionally, research done at the Sloan School has been the essential building block for all teaching programs. The dissemination of knowledge continues to be based on formation of that intellectual capital, and the School continues to maintain its position of research leadership among graduate schools of management.

These research efforts continue to focus primarily on private sector activities but public and not-for-profit sector areas attract steadily enhanced research interest. The problems of effective management and delivery of health and medical services are a major vein in this newer area of management research. Graduate research assistants have continued to play an important contributory role in the School's research and many fine theses emerge from these assistantships.

This section summarizes, by major functional or disciplinary groupings, some of the School's most recent research thrusts. The groupings are necessarily arbitrary, since a number of the projects cross functional lines and draw on several disciplines. The Working Paper series continues to include early versions of research plans and results. Seminars, summer programs, and other special programs also serve as launching pads for many of these newly generated research results.

### Human Factors in Management

The School's faculty in the Groups of Organizational Studies, the Management of Science and Technology, and in Manpower and Industrial Relations all focus in one way or another on the human factors in management, and draw on a mix of disciplinary bases -- psychology, sociology, economics, and other behavioral sciences.

*Organization Studies*

Research during 1971-72 by Professor Schein, chairman of the group, focused on professional and managerial careers. Through analysis of data gathered under the sponsorship of the Carnegie Commission on Higher Education, an attempt was made to conceptualize and describe career patterns in managers, particularly among alumni of M.I.T. In a related study, Professional Education: Some New Directions, an effort was made to understand the development of the professions in a rapidly changing society and the implications of these developments for professional education. Both projects represent an effort to understand career development throughout the life cycle.

Professor David A. Kolb has been involved, along with Professors Schein and Irwin M. Rubin, in an intensive analysis of the data collected on what happens to freshmen in their efforts to adapt to the M.I.T. culture -- a project funded by the Land Grant to M.I.T. In addition, he has continued his own research on individual learning styles and the learning process. He has developed a test as a means of identifying the approach to learning which is most effective in various academic disciplines and occupations. Professor Kolb is also currently writing a book reporting on his earlier research on self-directed change and helping relationships, particularly those in international assistance programs and in educational institutions.

Professor Rubin, besides collaborating on the study of M.I.T. freshmen, worked with Mr. Richard Beckhard on the development of a project to design and test new teaching materials for health education. They received one of the first grants from the Robert Wood Johnson Foundation to support this work on "Educational Programs for Health Management."

Richard Beckhard, Senior Lecturer, has been doing additional research in the health delivery field and has also worked on a research design for the development of a modified classroom-field practice teaching model in which students work in organizations making interventions that are defined by the using organization as both timely and relevant and yet are within the competence of the students.

Professor Leo B. Moore's research is in the two related areas of management development and management education. He has several company studies under way to understand the management development process as a part of organizational life. Senior Lecturer Peter P. Gil has continued to explore ways in which industry could derive greater benefit from the participation of its managers in executive development programs.

Research by Professor Galbraith has focused on the preliminary test of an organization design model which relates variations in organization forms to the organization's information-processing capacity. The design variables which can increase information-processing capacity are the authority structure, the reward system, and the information systems of an organization. Data was collected at Western Electric by Professor Galbraith and by Professor Milton L. Lavin who is collaborating with Professor Galbraith on this project. A second avenue for testing the theory has involved the construction of a computer simulation model of an organizational hierarchy, but this model has not been tested yet.

Professor Lavin, in addition to the work with Professor Galbraith at Western Electric, has done other exploratory work at Bell Telephone Laboratories on the same subject. Professor Lavin, with Professors Thomas P. Gerrity and Scott-Morton and several graduate students, also has begun a program of research on computer aided problem solving. The present focus of this research is on the design of aids (generalized symbol manipulation routines) to support the several phases of a "choice" or selection process.

Senior Lecturer Lotte Bailyn has been involved in the analysis of data collected on M.I.T. alumni under the Carnegie Commission sponsorship with Professor Schein. Based on this research, Dr. Bailyn has done in-depth analysis of the relationship of career to family, which resulted in her presentation of a paper (to be published in the coming year) to the New York Academy of Science sponsored conference on successful women in science.

*Management of Science and Technology*

In this related organization studies field, Professor Marquis and his colleagues continued their studies of the management of scientific and technological organizations, and on the process of technological innovation. Professor Marquis has undertaken analysis of data from various studies, consolidating and integrating the diverse findings in the preparation of models and of a general book on innovation. He also has directed several studies of project management in different situations.

Professor Farris is engaged in a longitudinal study of creativity, performance, and career development of scientists and engineers, and related factors in the managment of a laboratory.

Professor Allen continued his research in the structure of communication networks in technical organizations. He has extended his research to the problems of integrating new employees into the communication network of large organizations and to a major investigation of international technology transfer.

Professors Roberts and Galbraith, whose research is described elsewhere, are associated closely with the above program and are active participants in related teaching. During the year 11 students completed theses in the subject.

*Manpower and Industrial Relations*

As the Industrial Relations Section observes its thirty-fifth anniversary at M.I.T., the research efforts of its members progress in established areas as well as in new projects.

The Kendall Square Urban Renewal Employment and Business Location Study was completed during this past summer by Professor Francis M. McLaughlin, who was visiting professor during 1970-71, on leave from Boston College. This study, begun some years ago under a grant from the Ford Foundation, involves a detailed analysis of the effects of urban renewal on displaced firms and their employees, who were interviewed or contacted on three different occasions after displacement.

The research contract with the Manpower Administration of the U.S. Department of Labor on Labor Market Information Systems and the Disadvantaged has involved the active participation of two faculty members, Professors James E. Annable and Michael J. Piore (of the Department of Economics). Professor Annable has continued his research on the effects of recruitment policies of firms in several industries on the labor market information networks used by job applicants. Professor Piore has begun a study of labor market information networks used by Puerto Rican migrants to the Boston area. Additional studies under this contract have been by graduate students and by Harvard University researchers under a subcontract. The entire project is under the general supervision of Professor Myers.

Professor Mills has several research projects under way. He is completing a book-length manuscript on the theory and practice of wage controls in the United States, viewed historically in the context of the recent Phase 2 pay controls and the experience of the Construction Industry Stabilization Committee, of which he is secretary and deputy chairman. He also is engaged in a study of the application of computer technology to the construction industry labor market. This is supported by the U.S. Department of Labor, through the M.I.T. – Harvard Joint Center for Urban Studies. Finally, he is working on a study of construction management

in the United States, supported by a grant from the Ford Foundation. Professor Mills's book, Industrial Relations and Manpower in Construction, was published by The M.I.T. Press last spring. Several other articles on wage stabilization were published during the year. During the past year, Professor Mills was given a McGraw-Hill Engineering News-Record award "for outstanding contributions to the construction industry in the United States."

In addition to his work on the Department of Labor contract, Professor Annable has published two papers during the year and has been working on two others: "The Structure of Wages: A Theoretical and Empirical Analysis," and "The ICC, the IBT, and the Cartelization of the American Trucking Industry."

Senior Lecturer Jacks completed his initial research on productivity in the shoe industry, which was published by the National Commission on Productivity in August, 1971, under the title, Productivity Issues in the Domestic Shoe Industry. He has continued further research on this problem with Commission support. Professor Myers wrote an invited paper, "The Future of Personnel Management," for the inaugural issue of a new British journal, Personnel Review, published in London last fall. He also completed during the past summer a first draft of a paper, "Business Responsibilities for Employee Relations," as one of ten papers on "The Social and Economic Responsibilities of U.S. Business," to be published by the Brookings Institution early in 1973. The seventh edition of Personnel Administration was completed by Professor Myers with Professor Emeritus Paul Pigors and will be published January 1, 1973.

The Fifteenth Scanlon Plan Conference, under the direction of Fred Lesieur, who still meets various undergraduate and graduate classes during one week each spring and fall term, was held November 2-3, 1972. Mr. Lesieur, formerly on the staff of the Section following the death of Joseph Scanlon in 1956, is now an independent consultant in California. The conference is held every other year, and it attracts management and labor teams from companies which use the Plan as a means of exchanging experiences. Companies interested in exploring the possibilities of this labor-management cooperation plan, with or without unions, also come to the conference, for which fees are charged to cover expenses and to provide some funds for the Joseph N. Scanlon Memorial Fellowship, which finances one graduate fellowship in industrial relations each year.

The Section also provided financial support for the publication of the bimonthly annotated Industrial Relations Library Accession Bulletin, which classifies new literature in manpower and industrial relations (defined broadly) under a number of listed headings. For example, the May-June-July 1972 summer issue, No. 185 in a long series, contained 39 subject headings in 24 pages. Copies of this Bulletin are sent to firms supporting the work of the Section, in quantities they request, and also to libraries and teachers at other universities.

## Economics and Finance

The second major domain on which the School's teaching and research programs build is economics and finance.

Professor Sidney S. Alexander, head of the group, continued his research on the economic and political problems of the Middle East, on the foundations of policy, and on the pure theory of international trade. He also contributed to the development of the economics curriculum of the Accelerated Graduate Program in Management.

Professor Paul W. MacAvoy, working in the area of public regulation and operation of enterprise, completed a book on the Federal Power Commission. This book, co-authored with Professor Stephen Breyer of Harvard Law School, evaluates the performance of this Federal agency in terms of its effects on gas and electricity production, as compared to its intended or promised effects, and as compared to those from alternative forms of organization. The

study is to be published by the Brookings Institution. Further work along these lines includes the development with Professor Robert S. Pindyck of an econometric model of natural gas to evaluate national policy to ameliorate the gas shortage; this has been carried out under a National Science Foundation grant to M. I. T. for interdepartmental research on energy problems. Also Professor MacAvoy and Dean Pounds have initiated new activities in public enterprise with the government of Indonesia. Under the sponsorship of the Ford Foundation, they have been advising the Minister of Finance on organization to add to the efficiency of 150 government companies under ministry control. Further consultation and possible training of government and company executives are contemplated.

Professor Edwin Kuh was on leave in 1971-72 to organize the National Bureau of Economic Research, Computer Research Center for Economics and Management Science with an initial two-year grant of $1,500,000 from the National Science Foundation. The Center is engaged in major software, development of statistical data analysis, mathematical programming, and econometrics.

Professor Lester C. Thurow's research during the past year has focused on the mechanisms by which individuals are assigned to jobs in the labor market. This has led to a series of papers on the structure of the American distribution of earnings which has appeared in The Public Interest, a staff report for the Joint Economic Committee, and to a collection of essays for the Carnegie Commission on Higher Education.

Professor Pindyck has been engaged in research on problems in the energy sector, conducting studies on demand and supply, particularly in the natural gas industry, with implications for regulatory policy. He also has been doing work on applications of optimal control theory to economic policy and planning.

Institute Professor Modigliani's research falls into four main areas. He has continued his association with the M.I.T. – University of Pennsylvania – Social Science Research Council Econometrics Model of the United States, originally developed in cooperation with the Federal Reserve Board. In this capacity he has contributed to the updating and overhauling of some sectors and to the design of simulations of alternative stabilization policies. The monograph which reports on this model is about to reach completion. He has pursued research on the pressing problem of the design of an international payment mechanism to replace the Bretton Woods system. He has been concerned particularly with the relative merits of crawling pegs versus fixed parities, on the one hand, and floating exchanges, on the other. He has continued his work on the wage price mechanism, both in developed and developing countries. A monograph collecting a number of essays in this area was published in Italian by the Einaudi Foundation. Finally, he has continued to devote major attention to research in the capital markets. A study of the forces determining the flow of savings through the major financial intermediaries commercial banks, savings banks, insurance companies has just been published in Savings Deposits, Mortgages, and Housing.

Professor Daniel M. Holland, who was engaged in a number of research studies, continued his project on the effects of effort on business executives and the income and tax characteristics of high-salaried persons. He prepared a paper on measuring tax evasion (with Professor Oliver Oldman of Harvard Law School) for the Inter-American Center of Tax Administrators; prepared a paper for the President's Committee on Financial Structure and Regulation (Hunt Commission) on Tax Incentives for Saving; studied the revenue structure of Djakarta (Indonesia) for the World Bank; and undertook (with Professor Oldman) a technical assistance research project for that city designed to improve its property tax. Professor Holland also worked with Professor Scholes on a study of stock option valuation for the U.S. Treasury, and prepared (with Professor Oldman) a report on urban finances and expenditures for the Boston Strategy Group Seminar.

Professor Stewart C. Myers has continued work in a variety of research areas. He has worked out procedures for applying modern finance theory to problems of government regulation of business and is developing a model of firm behavior under regulation and uncertainty. Professor Myers is also studying how financing and investment decisions interact and how these interactions affect the firms' cost of capital. With Professor Pogue, he is developing a linear programming approach to long-range financial planning.

Professor Scholes finished the study he has been working on with Professor Holland of a project for the U.S. Treasury on the valuation and taxing of executive stock options. He completed research papers with various co-authors on option pricing, the valuation of corporate liabilities, the testing of the option pricing model, and the efficiency of the call option market. He is working on the effects of dividend payouts and dividend yields on share price, the effects of bond returns on share returns, and the structure of risk and return in the market.

Professor Robert C. Merton continues to work on a dynamic equilibrium theory of capital markets under uncertainty; intertemporal optimal consumption and portfolio decision rules; the pricing of capital assets and liabilities; the effect of default and bankruptcy on the capital markets; and the term and risk structures of interest rates.

Professor Pogue worked on research in corporate financial planning, international capital markets, and investment management. In corporate finance he completed work (with Professor Myers) on an optimization model which jointly determines the asset and liability structure for one firm. In the area of international finance he worked on the application of capital asset pricing to European securities. Finally, Professor Modigliani and Professor Pogue completed a study of investment company incentive fee plans, examining the impact of different performance measurement schemes on the amounts, timing, and volatility of the compensation received by investment advisors.

## Management Science

The Management Science Group is the School's third principal focus of research and teaching efforts. It is concerned broadly with models, information systems, and managerial decision making. The subject matter may be described as management decision systems or decision support systems. It covers a spectrum of knowledge and activities that starts with the manager and his problems, whether operational or planning, structured or unstructured, and extends back to his technological support.

The research of the Management Science Group can be classified usefully into process and methodology, although the nature of the field is such that developments often take place in both at once. The description of research into management process is subdivided into major public issues, nonprofit organizations, and business enterprise. Research on methodology is divided into planning and control, operations research, and computer systems.

### *Management Process*

Public management problems have occupied an increasing portion of the group's concern, just as they have in society at large. Among such problems none is more critical than the uncontrolled growth of world population. A project, under the general supervision of Professor Urban, has been under way for some time to apply modern management science techniques to a piece of that problem -- the management of a family planning organization on a city or country basis. A planning and monitoring system built around a model and a computerized data base has been developed and installed in Atlanta, Georgia. Installations are now starting in several other U.S. cities and in one or two developing countries. Much of the follow-through on these family planning systems is being carried out by recent graduates of the Sloan School. Dr. Ronald W. O'Connor, Professor Naert, and Professor Silk also have been involved in the project.

The United States faces increasing fuel costs, air pollution from power generators, brown-outs, and, generally, a set of problems now called the "energy crisis." M.I.T. as a whole is broadly involved with energy issues, and, as a part of this effort, members of the group are bringing management science techniques to bear on several problems in the natural gas subsector. The process of exploring for new gas reserves, long a subject for the normative application of decision analysis by individual companies, is the focus of a descriptive model which, when combined with other pieces of the energy puzzle, will be designed to assist in national policy making. Another piece is the natural gas distribution network. Its operation is being studied using the techniques of mathematical programming. Professor Gordon M. Kaufman continues to explore these issues.

National attention has been drawn recently to U.S. productivity. By normal economic measures productivity in this country has lagged dramatically behind that of Japan and a number of other fast-growing countries. A project directed by Senior Lecturer Gordon F. Bloom has been examining productivity in food marketing and has uncovered inefficiencies in transportation, materials handling, and carton standardization which offer significant opportunities for improvements.

Democracy requires more than periodic elections in order for citizens to inform and affect government. A project on citizen feedback systems, led by Professor Little has been seeking to develop methods by which information from citizens can be directed to societal institutions, especially government, in order to improve their functioning. A first stage in the project involved working with Governor Luis Ferré in Puerto Rico to install a service feedback system to improve government response to citizen inquiries, requests, and complaints and, at the same time, to develop better information for government about citizen concerns. Subsequent work in Massachusetts has explored citizen involvement techniques, including technology aided group meetings, ballot-like questionnaires on public issues delivered through news media, and interactive computer models for use by citizen groups. Such techniques open possibilities for developing and evoking better informed citizen participation in public issues.

One criticism sometimes leveled at the production-distribution system in this country is that, because of competitive pressures at the final sales point, products may be designed with a lower initial price and higher subsequent service costs than may be best from an overall system point of view. Consumer complaints are high and a number of manufacturers have installed service "hotlines." A project under the direction of Professor Hausman is studying consumer durables. A structure is being developed to analyze the durability, reliability, and maintainability of consumer durables as affected by various product design and marketing strategies. In particular, an investigation is under way of the effect of the mandatory offer of a service contract to the consumer so as to present him or her with an estimate of expected total system cost at the time of purchase.

The quality, cost, and geographic and socioeconomic distribution of medical care continue to attract widespread attention.

Professor G. Anthony Gorry's long-range research project deals with potential applications of the computer in medical diagnosis and therapy. Management science techniques from decision analysis have provided a framework for describing the diagnosis and treatment of acute renal failure. A computer program has been successful in duplicating the decisions of expert clinicians in about 90 percent of the cases considered. Fundamental research continues on knowledge based systems with an intermediate goal of developing methods for representing large bodies of knowledge within a computer, and a long-range goal of applying such methods to medical diagnosis and treatment.

The management problems of private nonprofit institutions are being studied in various

projects within the Management Science Group. A major continuing project under the direction of Professor John F. Rockart is developing management control and decision support systems for medical clinics, specifically the Lahey Clinic in Boston. Improvements have been achieved in service and efficiency both for patient and doctor through the application of management science techniques to patient scheduling, data analysis of medical history questionnaires, and data-reporting systems. Other projects within the group have dealt with educational institutions. These have included the management of Master in Business Administration programs, the impact of technology on higher education, and a study of university investing and corporate responsibility. Professors Scott-Morton, Edward H. Bowman, and Zannetos and Senior Lecturer Amstutz all have been involved in these efforts.

Business corporations produce and distribute the great bulk of goods and services in the U.S. and provide the economic foundation for social programs of the public sector. A variety of activities within the group deal with the applications of management science to improve the efficiency of the management of companies, large and small. One example is the area of marketing. The basic work of the past ten years in information systems, models, and time shared computing is now paying off in applications. Members of the group have been among the principal developers and implementers of this technology. Models and systems have been developed to address marketing management problems such as new product introduction, media planning, distribution of effort across the marketing mix, and sales force allocation. A contemporary decision support system for a marketing manager combines models of process, on-line data banks, statistical manipulation capability, and optimization routines. The gradual evolution of such systems is now taking place in dozens of corporations, with the faculty and graduates of the Sloan School playing a leading role. Professors Little, Silk, Urban, and Naert have continued to spearhead these research efforts.

Production and distribution systems are another area of application. Multistage production processes, forecasting for production control, and the coordination of aggregate and detailed scheduling decisions are areas of current research by Professors Kleindorfer and Hausman. A decision model for optimal equipment, maintenance, rebuilding, and replacement has been developed under the supervision of Professor Jeremy F. Shapiro for an application in the mining industry.

*Methodology*

Benefits from applications depend on a build up of basic methodological knowledge. The group is particularly active in computers, operations research, statistics, and the theory of planning and control.

A major thrust in operations research has been mathematical optimization. Work has centered on integer programming, mixed-integer programming, and the optimization of large time-dependent systems. In integer programming, special emphasis has been placed on computational methods that are based on a group-theoretic approach and on combining integer programming theory with duality theory. Computational results with large problems are very encouraging. Professors Shapiro and Magnanti are at the center of these activities.

A second important research area encompasses decision analysis and statistics. Developments in the Bayesian analysis of simultaneous equation systems are making possible the incorporation of prior information into complex statistical analyses in a formal way. Research on order statistics from dependent processes is seeking to establish the effect of statistical dependence on various statistical procedures. Certain fundamental problems in aggregating micro-regression models to permit macro-regression analysis have been overcome. A very common statistical task is the comparison of means. A new multiple comparison procedure based on gaps instead of range is under development. Finally, certain results have emerged in sales forecasting, both with respect to the data-generating process that is

appropriate to describe a particular sales series, and to the timing and magnitude of peak sales of a new product. Professors Kaufman, Roy E. Welsch, and Hausman have directed a portion of their research efforts here.

Research related to the computer is taking place on several levels. At a very basic level is work on automatic programming and other knowledge based systems. This work overlaps in personnel and content with Project MAC. A fundamental and long-range sub-project initiated by Professor William A. Martin seeks to automate the design and implementation of management information systems. Another project is the previously mentioned work on medical diagnosis. At a different level Professor Jones's work is almost complete on an on-line, PL/I-based simulation language. Still another example is Professor Ness's effort to design a compact, on-line decision support system containing a model building language, a data base capability, a set of statistical routines, and a report generator.

Information systems have long been difficult and expensive problems for top management, and yet increasingly important for planning and control. Steps have been taken to lay out a framework for viewing MIS. The goal is to assist management in understanding the issues and allocating resources to this area. At the same time studies are under way to see how managers actually use computerized support systems. This latter work is going on with portfolio managers in a Chicago bank. Finally a project is under way to develop a methodology for building models for decision makers, particularly models for assisting management planning and control. A multiple-stage process has been identified which lays out for the management scientist the many steps necessary (besides just building the model) to be sure his work will, in fact, be used by managers. Professors Scott-Morton, Gorry, and Urban are involved in these projects.

## System Dynamics

System dynamics methods and applications have been extended to a variety of areas during the past year. The Rockefeller Brothers Fund is sponsoring a new three-year research program directed by Professor Forrester on the dynamics of social and economic change at the national level. This will interrelate environmental, demographic, employment, governmental, industrial, and financial sectors in a study of both short-term and long-term dynamics of fluctuation and growth.

Vice-Chancellor Leigh Secrest of Texas Christian University visited for the spring term to study with Professor Henize in research on a model of an electrical utility with emphasis on investment, environmental issues, and regional development.

Professor Henize developed a second-term subject in principles of systems taught for the first time in the spring. This extends the teaching of system dynamics another step toward a full curriculum and gives stronger support to the growing research in the field. In his own research Professor Henize has been developing a dynamic model of the labor market interrelating employment, production, and inflation.

The Urban Dynamics Group, led by Louis Alfeld, extended urban modeling to explore new questions and structures with support from the Independence Fund in Philadelphia and the Committee of the Permanent Charity Fund of Boston. As a consequence of master's thesis research by Walter W. Schroeder in relating urban dynamics to Lowell, Massachusetts, a program has been established by the Department of Housing and Urban Development to adapt the earlier urban dynamics models to become a more specific guide in the multitude of decisions that a city must make. The urban group has started a new urban dynamics subject, conducted familiarization sessions for members of the state legislature and business organizations, extended the urban dynamics component of the Urban Executives Program, and started a project with Concord, Massachusetts, on suburban development and change.

Limits to Growth, written by the group with Professor Meadows, was published in March with translations into a dozen languages. It immediately became a subject of world-wide discussion as it extended the debate started by Professor Forrester's World Dynamics. It has been the subject of numerous reviews, editorials, and symposia.

Grants from Kenneth J. Germeshausen, the General Electric Foundation, the Zaffaroni Foundation, and the Cummins Engine Company helped to sustain continuity of the research and allowed the School to strengthen the staff.

Professor Forrester and Jørgen Randers conducted a two-day program for the Board of Overseas Missions of the National Council of Churches. The papers and discussion developed implications of the transition from economic growth to equilibrium for the value-setting institutions in society. As a consequence of the meeting, the National Council of Churches is funding the doctorate research by Mr. Randers on the dynamics of the propagation of new values and goals.

## Corporate Strategy (Business Policy)

The field of strategy, which Professor Bowman initiated in the School, continues to grow. Professor Bowman is on leave with the European Institute for Advanced Studies in Management, Brussels, Belgium. In his absence, Professor Haire is monitoring the development of the area. In course work, strategy has become a required subject for Sloan Fellows, a part of the Senior Executive Program, and a large and lively part of the regular master's curriculum.

In addition to the regular subject offerings, Professor Carroll Wilson has instituted a seminar on strategies for sustainable growth. The subject matter brings together the conceptual framework provided by The Limits of Growth, which grew out of Sloan School work in system dynamics, and Professor Wilson's activity in and knowledge of supranational attempts to harness high-level technology to the management of the quality of life.

In the summer of 1971, Professor Bowman, at the request of the President of M.I.T. and a subcommittee of the Executive Committee of the M.I.T. Corporation, undertook a major investigation of university investing and corporate responsibility. The report was published by the Institute. It attacked, specifically, the knotty problem of the responsibility of the impersonal investor for using the leverage of his equity to vote his evaluation of particular companies' actions as corporate citizens. The work begun in this study is being continued as a major research project in the European community by Professor Bowman.

A variety of research projects -- at present represented mainly by master's theses by Sloan Fellows and regular master's students -- are springing up in the area. As the interest in the field crystallizes, it is likely that these research interests will coalesce into a limited number of identifiable streams of investigation. At the same time, the student demand for course work is growing, and it probably will be necessary to add staff in this area.

## International Management

The international context for management operations continues as an explicit focus of faculty research and teaching. Under the general guidance of Senior Lecturer Richard D. Robinson, a study was completed of the expropriation of the Zambian copper industry, the essence of which was reduced to a series of case studies. Other research leading to distillation into case studies for teaching purposes involved a series of negotiations for licenses in Eastern Europe and an analysis of recent labor-management problems of the Ford Motor Company of the United Kingdom. Senior Lecturer Robinson also began a state-of-the-art textbook on international management. During the year, students majoring in the international management area conducted field research in Germany, France, Colombia, United Kingdom, Japan, and Zambia. Michael Bernhart undertook a study of Colombian export marketing channels

under the joint sponsorship of the School and the Colombian export promotion agency, PROEXPO. It was possible to identify the most efficient channels of market information and to specify some of the societal costs incurred by vigorous promotion of exports.

Other members of the faculty were active in research involving international dimensions. Professor David Durand, while a guest professor at the Technical University in Berlin, worked on rates of return from investments, a field in which Germans have done much work almost entirely unknown in the United States. Professor Stuart Madnick was involved in the development and specifications of an advanced "software factory" facility to service the needs of Olivetti's future small computer activities in Europe. Professor Modigliani, as noted earlier, continued his ongoing research and writing on the reform of the international monetary system and continued to act as economic advisor to the Bank of Italy, the Bank of Spain, and the Swedish Business Cycles Institute. In each case, his work involved the construction of an econometric model for the respective country.

Professor Allen was involved in two ongoing studies dealing with the transmission and diffusion of scientific and technological information in Ireland. The first study (sponsored by the Irish Science Council) sought to identify the way in which the research and development community of a developing country acquired foreign scientific and technical information and how that information is disseminated to members of the local scientific community. This research led to the identification of technological gatekeepers, individuals who serve as effective conduits for scientific and technological information from abroad. The roles played by universities, private firms, and the government were specified in the diffusion process of new information crossing the national boundary from abroad. The second study (sponsored by the Irish Industrial Development Authority) sought to identify how firms which do not support research and development obtained technical information. It was established that universities in Ireland play a minor role in this process and that foreign technology most frequently came through direct contacts with foreign suppliers and foreign producers in the same industry.

The four-year action-research project directed to providing technical assistance to the Banco Nacional do Desenvolvimento Economico (BNDE) was concluded. This assistance included training courses, organizational development, and improvement of management information systems. Professor Farris, a principal in the program since its inception, evaluated the project and published his results. Two direct spin-offs from the project were a fellowship program for Brazilians to study abroad for doctoral degrees in social and organizational psychology, and the creation of CEBRAE, a national center for assistance to small and medium-size firms which will continue to run the training programs begun in the BNDE-M. I. T. project. The larger impact of the BNDE project may be seen in subsequent efforts to create a national center for organizational research in Brazil. Professor Farris has continued to be a principal in the policy discussions regarding the creation of this entity.

## Public Sector Management

The Sloan School's general commitment to public sector research has continued to grow. Over one-third of the faculty have major research projects under way in this area. Some of these efforts have been referred to in earlier sections. The following paragraphs pull together, in sectoral groupings, a further sample of this ongoing research.

The largest concentration of research is in health systems management with research by Professors Gorry, Roberts, Rockart, Rubin, Urban, and Senior Lecturers Beckhard and White. During this past year, the management of health care delivery has blossomed further as an area of research, curriculum development, and experimentation. Senior Lecturer Beckhard, in collaboration with Professor Rubin, continued his action research project at the Martin Luther King, Jr. Health Center on the effectiveness of interdisciplinary health teams and the organizational issues involved in the team delivery of comprehensive health care. Two project reports were published and a major proposal was developed for the creation of educational

models and curricula for training health teams and health organizational development specialists.

Professor Gorry extended his research in the area of computer aided medical decision-making. Supported by funds from the National Library of Medicine and the National Institutes of Health, Professor Gorry has worked closely with Dr. William B. Schwartz of the Tufts-New England Medical Center on the development and implementation of interactive computer programs for the analysis of diagnostic and therapeutic problems.

Professor Roberts continued his work in the application of system dynamics analysis and modeling to the area of health care delivery. In collaboration with Mr. Pugh and Senior Lecturer White, a prototype was developed to study the feasibility of modeling alternative approaches to universal entitlement to health care. With Professor Gilbert Levin of the Albert Einstein College of Medicine, Professor Roberts continued his modeling efforts on community mental health centers, with special attention to a large-scale effort on heroin addiction.

Professor Rockart has continued his work with the Lahey Clinic in the general area of medical operations and management control. His efforts covered four areas: 1) the scheduling of ambulatory care; 2) the improvement of physician efficiency by improved medical reporting systems; 3) the design of a management control system for the Lahey Clinic; and 4) the development of decision support systems for the appointment secretaries.

Professor Urban further extended his activities in the development and testing of an on-line planning model for managers of metropolitan family planning programs. Department of Health, Education, and Welfare (HEW) funding during the past year supported this effort in which Dr. Ronald O'Connor also was involved. The model will be tested in five cities during the coming year under an additional HEW grant and development of the planning model for international settings is under way.

Senior Lecturer White served as principal investigator for a planning study on universal entitlement to health care that was undertaken by the Institute of Medicine of the National Academy of Sciences. In addition Senior Lecturer White continued his action research efforts as a member of the Massachusetts Medical Rate-Setting Commission.

During the year three new teaching efforts were initiated in the area of health management, all on an experimental basis. Professors Roberts, Rockart, and Urban jointly organized and taught a research seminar on quantitative approaches to health systems, stressing the role of computer models and information systems in health care delivery. Professor Roberts also organized for scheduled summer presentation a special one-week course on health system dynamics. Senior Lecturer Beckhard and Professor Roberts worked with the Management Advancement Program of the Association of American Medical Schools to design and develop a one-week course in management for 20 medical school deans, to be presented for the first time at Endicott House at the end of the summer.

In addition, Deans Pounds and Abraham J. Siegel and Professor Roberts have represented the Sloan School in an extensive series of discussions with other M.I.T. departments and with the new Harvard — M.I.T. Program in Health Sciences and Technology. These discussions have been aimed at the creation of an Institute-wide program in health planning and management that would lead to broadly expanded research and educational opportunities in this area in which the Sloan School would continue to make a key contribution.

In the field of education management, Professor Zannetos examined the impact of technology. Professor Kolb studied social psychology of education. The form and timing of professional

education was researched by Professor Schein. Professor Little examined the modeling of state aid to education and Professor Bowman studied management of universities.

Major portions of this research were funded by grants from the Carnegie Commission on Higher Education and the Ford Foundation. The study of professional education, as a part of the broad topic of the form and timing of higher education, was completed by Professor Schein and published as the tenth in a series of profiles sponsored by the Carnegie Commission under the title Professional Education: Some New Directions. The objective of this study was to suggest ways that professional schools could make their educational format more responsive to emerging needs in the various professions. Professor Schein also has continued his analysis of a special M.I.T. alumni survey of the Classes of 1951, 1955, and 1959 to determine the relationship of undergraduate education to graduate education, occupation, income, job attitudes, career patterns, and other variables. Professor Lotte Bailyn has collaborated on these studies.

A second project supported by these funds has been completed by Senior Lecturer Amstutz, Katherine A. Moore, and Thomas F. Riesing in working paper form, entitled "The Management of Education." This deals with the development of a model to evaluate progress toward educational objectives. Beginning with the master's program model developed by Senior Lecturer Amstutz earlier in the Sloan School, the study tests the model in four other graduate management schools and in samples of undergraduates in other colleges. The model includes inputs by faculty on objectives of the subjects they offer; student objectives, attitudes and expectations; and perceived student changes resulting from enrollment in each subject. The monograph concludes with implications for educational policy makers and operations management.

A third project, still not completed, involves technology and education, under the direction of Professors Scott-Morton, Zannetos, Rockart, and Jarrod Wilcox. During the past year, work has continued on technology for higher education, including computer applications; areas of potential application in the learning process; efforts to meet these potential applications; and the expected and perceived impacts. The final manuscript on this study should be completed during 1972-73.

The work by Professor Bowman on the problem of the institutional investor (using a university as a case study) was supported by the Executive Committee of the M.I.T. Corporation.

The issues of labor management in the public sector, described in detail earlier, continued to receive attention. Senior Lecturer Bloom studied Negro employment in the supermarket industry while Professor Alan Patz studied the more general issues of manpower planning. Collective bargaining in public employment was addressed by Professor Annable. Research in the labor markets in less developed countries was carried out by Professor Annable.

The international setting molded a number of other studies in public sector issues. In addition to the study of labor conditions in international settings, Professor Allen studied the transfer of technology to less developed countries. Professor Farris conducted a research project that applied organization development and information system concepts to Brazilian banking. Professor MacAvoy worked with the Indonesian government in a study of economic development.

Regulated industry and the political process were among the other foci for some domestic public issues. In the U.S.A., economic aspects of public utility regulation were studied by Professor Stewart Myers. Professor Kaufman studied the statistical aspects of pollution. Professor MacAvoy analyzed the efficiency of the Federal Power Commission. Professor Little examined citizen feedback systems. Problems of urban renewal were studied by Professor Charles Myers and his colleagues. Professor Forrester's work on urban dynamics continued. His expanded systems dynamics model of the world has received continued effort

with additional work conducted by Professor Meadows.

Research activity in management in the public sector is significant and diverse. It is clear that a major research program now exists in the area of public systems and it is very likely that research in this area will continue to increase.

## International Programs

As part of a deliberate policy decision, the Sloan School has desisted from committing itself to provide a flow of services to overseas institutions. Although, as already made apparent in the section on international management research and elsewhere in this report, many individual faculty members have been very active overseas, the School itself has entered into no international contractual obligations. Rather, the School has been concentrating on improving and expanding its own capabilities in the international area with respect to faculty, subject offerings, and research.

Nonetheless, during the year, the School did in fact support and participate in several management education programs abroad, but on the basis of individual faculty involvement. Dean Pounds participated in the preparation of seminars on management sponsored jointly by the Ford Foundation and the U.S.S.R. State Committee for Science and Technology. A seminar in this series on the topic of human organizations was held in Kiev, U.S.S.R. in 1972. Professor Galbraith participated along with several U.S. and Soviet academicians currently active in the field.

Selection interviews for European Doctoral Fellowships were conducted in Bucharest by Dean Pounds and Dean William Dill of New York University during the summer of 1971. The Sloan School admits annually two European Doctoral Fellows to its doctoral program.

In 1969, Dr. Chandler H. Stevens went to Puerto Rico as a member of ex-Governor Ferré's staff to take part in the formation of the Governor's Advisory Council for the Development of Government Programs. With the aid of several M.I.T. professors, the Council has conducted studies on economic and developmental problems in Puerto Rico.

In 1971, Professor Piore (of the Department of Economics) became the Executive Director of the Council and continued the project with the assistance of Professors Thurow and Kuh of the Sloan School. The project essentially terminated when Professor Piore returned to the U.S. in August, 1972, after the research efforts were completed and spin-offs from the research were absorbed by the Puerto Rican government.

During the spring and summer of 1972, Professor Holland advised the government of Indonesia and the municipality of Djakarta in respect to improvements in Djakarta's property tax system. This project, undertaken with Professor Oldman of the Harvard Law School, has been completed.

Operaçion Desarrollo (Operation Development), an executive training program in Bogota, Columbia long has received the support of the School; Dean Pounds, Professor Michael Brower and Senior Lecturer Beckhard all led seminars for groups of senior Colombian executives. During the year, Dean Pounds was requested to provide policy guidance for the program and to present the opening seminars for the most recent cycle.

Further support to foreign institutions was provided by Professor Schein, who lectured to the European Management Forum in Davos, Switzerland, and serves as a faculty advisor to ISTUD, the Italian management school located in Milan. Senior Lecturer Robinson organized a study visit for a group of Japanese management students from the International Studies and Training Institute at Fujinomiya, Japan, to Harvard Business School and the

Sloan School. Professor David Durand was a guest lecturer at the Technical University in Berlin.

*International Visitors*

Dr. Oleg Alekseyevich Kossov was an exchange visitor to the United States having been nominated by the Academy of Sciences of the U.S.S.R. Dr. Kossov is a Section Chief of the Moscow Institute for Control Problems. Professors Roberts and Marquis acted as hosts for a six-month visit, during which time Dr. Kossov studied methods for the production of work organization analysis and control in scientific research organizations. While here for the spring term of 1972, Dr. Kossov held the title of Visiting Scholar.

Simon M. Andrew of Cheshire, England, was a Research Affiliate under the faculty sponsorship of Professor Roberts for the fall term of 1971. While here, Mr. Andrew investigated the relevance of research to the British chemical industry.

Dr. Arun Chaudhuri of the Indian Institute of Management, Calcutta, India was a Sloan Foundation Post-Doctoral Fellow for the fall term of 1971. Dean Thomas M. Hill was the host for Dr. Chaudhuri's visit.

## Staff Promotions and Changes

Professors Farris, Mills and Scholes have advanced to Associate Professor from Assistant Professor. Newly appointed to the staff of the School is Eleanor Chin, who became Administrative Assistant for Teaching Programs.

The School was fortunate to have with it as Visiting Associate Professor this year Dr. John H. Peters, who had been a Sloan Fellow during the past year and who stayed on to work with Professor Jay Forrester on research on the U.S. Public Health System. Professor Richard W. Cottle was also present as a Visiting Associate Professor. On leave from Stanford University, Professor Cottle worked closely with Professor John D.C. Little at the Operations Research Center during his stay at M.I.T.

Joining the School as a Senior Research Associate was Dr. Ronald O'Connor, who also was a Sloan Fellow last year. Dr. O'Connor has worked with Professor Glen Urban in the Family Planning Management Research Project.

Professor Ronald Wolff, on leave from the University of California at Berkeley, joined Professor Little at O.R.C. Professor Wolff did research in queuing theory.

Professor Jay M. Anderson worked with Professor Meadows and the World Dynamics research group for the year. His appointment was as a Visiting Associate Professor while on leave from Bryn Mawr College. Professor Anderson's work was supported by the U.S. Army Corps of Engineers, which provided him with a research grant to apply system dynamics techniques to problems of water resource development policy.

Dr. Herbert W. Lorber was at the Institute as a Postdoctoral Fellow with Professor Forrester's System Dynamics Group, as was Dr. Philip Clark Souers, on leave from Pfizer Pharmaceuticals to investigate possible application of system dynamics to health systems.

Professor G. Anthony Gorry was on leave during 1971-72, pursuing his research on computer aided medical decision making. This research was supported by a grant from the Public Health Service, National Institutes of Health. Professor Edwin Kuh was also on leave from the Sloan School to enable him to act as Executive Director of the NBER Computer Research Center for Economics and Management Science. Professor Carroll Wilson was away for three months during the fall of 1971 to be Senior Consultant for the U.N. Conference on the

Human Environment, which was held in 1972.

Professor Gordon Kaufman and Professor David Kolb returned from leave for the spring term, during which they were involved with a teaching assignment at the London School of Business. Professor Edgar Schein returned to teaching full time from his year's absence to complete his research effort for the Carnegie Commission on the Future of Higher Learning. Professor Silk returned after having finished his research on models for planning and measuring response to marketing communication.

Having served with the Sloan School since 1966, Professor Wallace Crowston left to join the Faculty of Administrative Studies at York University in Ontario, Canada. Professor Christopher R. Sprague has joined the faculty of the Wharton School of Finance and Commerce, and Professor Alan Patz, the University of Southern California in Los Angeles. Professor Milton Lavin has joined the staff of Technology Management, Inc. in Cambridge, as has Professor Carl Swanson. Professor Dennis Meadows is now associated with Dartmouth College.

* * * * *

As indicated at the outset of this report, the School's teaching and research activities of the year just summarized are to a considerable extent developments growing out of the School's basic initial strategy -- to develop a self-sustaining institution focusing on innovation and excellence in management education, able to attract outstanding faculty and students, and pursuing pure and applied research as a base for its educational programs.

The School's early strategy has, in the view of the Dean, produced at M.I.T., and at institutions across the country which have pursued similar strategies, schools which are respected as independent and self-sufficient entities in the specialized field of management. The Sloan School's strategy (where it has succeeded as it has at M.I.T.) has produced faculties and programs of research and teaching which are seen as meeting the highest standards of longer established professional schools such as those of engineering and medicine. Management schools, like these older schools, now have the capacity to draw the best concepts from the disciplines and to focus them on the professional concerns of their students.

However, this "separate but equal" result, which has tended to characterize all professional schools, may need to be modified. New programs of research and education in fields as diverse as energy, health, education, research and development, nutrition, and many others will require a more intimate combination of skills and attitudes than can be accomplished through coordinated but independent efforts by the relevant schools and departments. New programs aimed at taking advantage of disciplines which include, but also go well beyond, the field of management are required now. To accomplish them, multi-disciplinary programs of research and teaching which will reduce the intellectual indifference which sometimes arises across departmental and school boundaries are required.

Some current examples of needs in these new areas may illustrate the point, but the list is necessarily incomplete: 1) Health Planning and Management; 2) Energy Laboratory; 3) Environment; 4) Ocean Engineering and Sea Grant; 5) Information Systems; 6) Urban and Public Management; and 7) Education. In each of these broad areas newly recognized needs of society and opportunities for M.I.T. are developing. In each of these areas management cannot be regarded as a peripheral consideration, or as a set of ideas which can be added on to make technology and science somehow more effective. Management concepts and managers are central to each of these new areas of societal concern, and the School must be prepared to play its full part in the new fields and programs which will depend on it increasingly.

To accomplish such program and institutional innovation, considerable support for faculty development, basic research, and curriculum development is required to construct the same kind of broad intellectual base under these new areas which has served so well and has led to such fruitful program development in the field of management education as it is now defined. The principal challenge of the future decades may well lie in the Sloan School's and the society's capacities to foster the developments which will extend the School's potential impact on some of the major problems of our time.

WILLIAM F. POUNDS

# School of Science

This year saw a number of changes in the School of Science which reflect the dynamic world in which we live. Several new programs in education and research were begun, while others faded away.

The number of undergraduate majors in the School of Science increased again, as it has for the past three years, to 1,105 in September, 1971, from 1,050 the year before. The largest increase was in the Department of Biology where the number of undergraduate majors was 307, compared with 206 a year ago. The number of graduate students decreased from 973 to 899, as a result of the reduction in Federal funds for the support of graduate study. Looking ahead to the graduate enrollment in the fall of 1972, the School expects very nearly the same number as in the fall of 1971, rather than a further decrease. The number of postdoctoral positions was essentially the same in the fall of 1971 (276) as in the fall of 1970 (265), except for an increase in the Department of Nutrition and Food Science.

The efforts of the Departments of Biology, Chemistry, Mathematics, and Physics to improve the science requirement subjects taken by freshmen continued this year; Professor Charles E. Holt in the Department of Biology, Professor Arthur P. Mattuck in the Department of Mathematics, and Professor Robert I. Hulsizer in the Department of Physics were appointed by their department heads to supervise these and certain other aspects of undergraduate instruction. This year there was a significant increase in freshman enrollment in the more difficult options available to freshmen. The enrollments in 5.41, Introduction to Structure, Bonding, and Mechanism, and 7.01, General Biology, increased markedly, and both were offered for the first time in the spring, as well as in the fall. The enrollments in 8.012-8.022, a more mathematical version of freshman physics, and 8.013-8.023, the biomedical version of freshman physics, also increased substantially during the year. This year for the first time it was possible to satisfy the Institute requirements in chemistry, mathematics, and physics through the self-paced mode of instruction.

Other instructional programs which were highlighted by the Rogers' Task Force are the Undergraduate Seminar program and the Undergraduate Research Opportunities Program (U.R.O.P.). The number of undergraduate seminars in the School of Science was 11 in the fall of 1971 and 18 in the spring of 1972; 26 are being offered in the fall of 1972. The number of undergraduates in the School of Science working on a thesis during the fall was 52; the number of students in the School of Science registered for credit in the fall was 109, and in the spring 189. These are definitely minimum values and do not accurately reflect the impact this program has had on undergraduate instruction.

The undergraduate program in Interdisciplinary Science was approved by the M.I.T. faculty on October 20, 1971. This program, succeeding Course XII-B which was begun as an experimental program in 1968, provides students with the opportunity to develop majors in interdisciplinary fields which are not provided for by the regular departmental programs. A student's program, developed in discussions with his faculty advisor, must contain a coherent set of science subjects and must be approved by the committee for the program. The committee consists of: Professor James M. Austin, of the Department of Meteorology; Professor John M. Buchanan, of the Department of Biology; Professor Charles C. Counselman, of the Department of Earth and Planetary Sciences; Professor Louis N. Howard, of the Department of

Mathematics; Professor David N. Hume, of the Department of Chemistry; Professor Earle L. Lomon, of the Department of Physics; and Professor Sanford A. Miller, of the Department of Nutrition and Food Science. The Dean of Science serves as chairman, and Professor Counselman serves as registration officer.

The support of research in the School of Science increased slightly, probably just enough to cover the increased costs of research. The year saw the dedication of two new facilities which will provide increased opportunities for students and faculty in the School of Science. The George R. Wallace, Jr., Astrophysical Observatory, near Westford, Massachusetts, was dedicated on October 14, 1971. Mr. and Mrs. Wallace attended, and their remarks and interest made the occasion a very happy one. The Observatory, with its 24-inch and 16-inch reflectors in separate domes, has been in active use for research and instruction this year. Professor Thomas B. McCord, director of the Observatory, has developed a program of operating the large telescope with its new types of very sensitive detectors through a computer which also provides data processing.

On April 7, 1972, the William H. Bates Linear Accelerator at Middleton, Massachusetts, was dedicated in honor of the late Congressman William H. Bates. The LINAC will accelerate electrons to 400 million electron volts and will provide higher intensities and greater precision for the investigation of nuclei. Professor Peter T. Demos, director of the facility, and director of the Laboratory for Nuclear Science, has had the responsibility for planning, raising funds, and construction of this remarkable $7 million facility.

ROBERT A. ALBERTY

## Department of Biology

During the year, 307 undergraduate students concentrated in the life sciences and 95 were awarded the Bachelor of Science in this field; the previous year's figures were 206 and 60, respectively. Between July 1, 1971, and June 30, 1972, 30 doctorates and five Master of Science degrees were awarded in biology. There were 96 graduate students during the past year. The class entering in September, 1972, will bring the Department's total population of graduate students, which had fallen below the usual number of 100, to 114. Their quality is high; four among them have been awarded the rare National Science Foundation (NSF) predoctoral fellowships. Fortunately, all four of the Department's National Institutes of Health (NIH) training grants have been renewed. It will be able to support all newly entering students through training grants, research grants, and as teaching assistants. The Department again has been awarded an NSF grant for summer research by undergraduate students.

### Research

The research by members of the Department's faculty, research associates, research fellows, and graduate students is described in a publication entitled Research Summaries, which is available in Departmental headquarters.

Most of the research is in the area of cell biology and molecular biology. An important step was the creation of an electron microscope facility, planned and directed by Professor Jonathan King. The Department was able to obtain funds from NIH, NSF, and from M. I. T. for the purchase and installation of two new high-performance JEM 100B electron microscopes, new facilities for embedding and sectioning, and a new evaporator for shadowing nucleic acid preparations. The RCA 3G has been modified and upgraded so that it can be operated safely by novices, but still yield good results; a Siemans I is now reserved for high-resolution autoradiography, and the Department has a low-resolution, high-contrast Hitachi which is very useful for examining tissues and other large-scale specimens. It is quite likely that the increased ease of use and the improved quality of the results will lead to many more people making use of the electron microscope facility from now on.

## Personnel

Resignations: Professor Joel Brown, a neurophysiologist, left the Department to accept a position in the Department of Anatomy at Vanderbilt University. Professor Paul R. Gross has decided to leave in July, 1972, to become head of the Biology Department at the University of Rochester.

Appointments: The Department's policy on new appointments was strongly influenced by its teaching obligations and by its intention to increase the proportion of women on its faculty. The Department was very fortunate to find as a replacement for Professor Gross a young woman, a developmental biologist of great promise, Dr. Mary Lou Pardue, who obtained her Doctor of Philosophy at Yale University. She will join the faculty in July as associate professor. Her work on the hybridization of DNA in cell preparations is an important breakthrough in cell biology.

The need to strengthen the teaching of microbiology, particularly in the introductory laboratory subject Introduction to Experimental Biology, led to the appointment of Dr. Annamaria Torriani-Gorini as associate professor. Dr. Gorini, well known for her work on regulation, has been doing research in the Department under a Career Development Award from NIH.

The large increase in the number of students in biochemistry subjects made it necessary to add another biochemist to the Department's faculty. It was very fortunate to attract Dr. Malcolm L. Gefter from Columbia University. Dr. Gefter, who will join the faculty in September as associate professor, is considered one of the best and most promising young biochemists.

Another appointment which will strengthen the Department's program in biochemistry is a joint appointment with the Department of Chemistry. Dr. Christopher Walsh, who obtained his Doctor of Philosophy from Rockefeller University, has accepted the position of assistant professor for July, 1972. His laboratory will be located in the Department of Chemistry.

Professor Gene M. Brown will become associate head of the Department effective July, 1972, and Professor Charles E. Holt III will be appointed academic officer.

Promotions: Associate Professors David Baltimore and Ethan R. Signer were promoted to the rank of full professor effective July, 1972.

Awards: Professors David Botstein and Harvey F. Lodish have been awarded Research Career Development Awards by NIH.

BORIS MAGASANIK

## Department of Chemistry

Forty-four undergraduates were awarded the Bachelor of Science in chemistry this year. Two were employed by industry, while all others chose to continue their education as candidates for advanced degrees with substantial financial aid in the form of fellowships and teaching assistantships in colleges and universities throughout the country. The flexible curriculum, which provides for elective time in the third and particularly the fourth year to prepare for advanced study in medicine, business administration, law, oceanography, metallurgy, and chemical engineering, subject to the advice and approval of the faculty counselor, has provided an opportunity and background for a choice of professional careers. Many of the Department's students continue to prefer study in organic, physical, inorganic, and analytical chemistry, and to select independent study as an elective, which provides an opportunity to work under the direction of faculty members on problems which may be experimental or

theoretical and equivalent to a thesis.

Doctor of Philosophy degrees were awarded to 51 candidates. To date 1,284 Doctor of Philosophy degrees and 330 master's degrees have been awarded by the Department. With a few exceptions in which candidates for the doctoral degree with special qualifications were employed in industry, placement has been in temporary positions as postdoctoral fellows, research associates, and as instructors in academic institutions in the U.S.A. and in foreign countries -- such as Israel, Yugoslavia, England, and Venezuela.

## Curriculum

The options for entering undergraduate students in chemistry subjects are as follows: 5.41, Introduction to Structure, Bonding, and Mechanism; 5.60, Chemical Equilibrium; 3.091, Introduction to Solid-State Chemistry; and 7.01, General Biology.

The undergraduate enrollment in chemistry subjects continues to increase. Introduction to Structure, Bonding, and Mechanism, and Introduction to Chemical Experimentation are now being offered both terms in order to accommodate the large enrollments.

## Facilities

Renovation of the Department's space in Building 6 is now finished. The third and fourth floors were remodeled completely for inorganic chemistry, the second floor was converted to office space for the faculty and students in theoretical chemistry, and the physical chemistry space on the first floor was brought up to modern standards. Analytical chemistry has been moved to the third floor of Building 2 and additional space for physical chemistry provided in the basement. Some former organic research space on the fourth floor of Building 4 has been converted to inorganic research laboratories. These moves involved a minimal amount of renovation. Since the completion of the Dreyfus Building, the Department has relinquished approximately 20,000 square feet of space to other groups in the Institute.

On March 3, 1972, the new seminar room on the second floor of Building 6 was dedicated as the Isadore Amdur Room. The dedication was attended by over 100 friends of the late Professor Amdur.

## Research

Research in the Department of Chemistry is carried out by members of the faculty, postdoctoral fellows and associates, and graduate and undergraduate students. Research throughout the year continued at an active pace, in a large variety of fields, within chemistry and associated disciplines. Each year a few representative programs are included in this report.

Professor James W. Dubrin conducts experimental studies in chemical kinetics of excited species. Reactions of Translationally Excited H Atoms: This branch of chemical kinetics deals primarily with those reactive encounters occurring above the threshold energy. By photochemical means, H atoms having a known initial kinetic energy between 0.3-5 ev. may be introduced selectively into a "cold" reaction medium (0.04 ev.). It is then possible to determine the reaction probability of chemical reaction, e.g., $H + D_2$ $(CD_4)$ $HD + D(CD_3)$ as a function of the relative kinetic energy of the atomic hydrogen. In addition, certain of the kinematic aspects of these typical direct impact mode reactions may be examined quantitatively.

Professor Richard J. Lagow's general area of research is fluorine chemistry, high temperature chemistry, plasma chemistry and inorganic polymers. Fluorine Chemistry: A new technique for controlling the reactions of elemental fluorine with inorganic, organic, and polymeric systems has been developed recently. Much of the research in fluorine chemistry

is concerned with further extending the synthetic applications of this general new technique.

Professor Sidney M. Hecht's general area of research includes Design of Hetrocyclic Antimetabolites: During the past 15 years, a number of compounds have been isolated from fungi which are isomeric with normal nucleosides and which act as nucleoside antimetabolites or antagonists, i.e., which oppose the action of the nucleosides in several senses. This class of compounds is called the nucleoside antibiotics. Research in this area is based on the premise that additional classes of "nucleoside antibiotics" may be synthesized which will oppose the action of certain important biological transformations, and attention has focused on the antagonism of three key cellular functions. Initial work centers on antimetabolites designed to inhibit specifically, in certain senses, 1) ribonuclease action, 2) ATP utilization, and 3) cyclic AMP utilization. It is anticipated that these compounds will be useful in basic studies of important biological functions and, for those compounds with high tissue specificity, in the treatment of metabolic disorders.

Professor Paul R. Schimmel's general research field is chemical biophysics, relaxation spectrometry, and biochemistry. Experimental and theoretical investigations of the chemistry and of the physics of biological phenomena are of great current interest. Such investigations are being conducted by this research group. Absorption and fluorescence spectroscopy, the temperature-jump and ultrasonic relaxation methods, the stopped-flow method, and many conventional methods are being put into use in order to study various biological phenomena. In addition, biochemical studies of complex biological systems are under way.

Professor Richard C. Lord's current research includes infrared and Raman studies of compounds of biophysical interest. Spectroscopic and gravimetric work on the effects of the controlled hydration of DNA films has been completed and published. Spectroscopic studies also are being carried out on native enzymes, including lysozyme, ribonuclease and chymotrypsin, insulin, polyadenylic acid, and other biopolymers to investigate their structures and stability in aqueous solution at various pH levels. Association constants for suitable derivatives of guanine and cytosine and of uracil and adenine in nonaqueous solvents have been studied to ascertain the strength of H-bonding in these base-pair associations. Various other problems in H-bonding and in the structure of biological high-polymers are also under attack.

Current research also includes studies in far-infrared spectroscopy. One of the topics under this broad heading is the study of molecules with strongly anharmonic potential functions associated with molecular inversion. Such potential functions produce a rich set of vibrational energy levels whose spacings fall in the far infrared and whose analysis leads to the evaluation of the coefficients in the above potential. The coefficients provide an accurate value of the potential barrier separating the equivalent potential minima and also fix other parameters such as the equilibrium angle of ring distortion. These studies are giving insight into the relative magnitudes of intramolecular forces originating from barriers to internal rotation, bond strain, and the like. Little work has been done on six-membered and larger rings, but their study appears to be worthwhile.

Professor Clark C. Stephenson is doing research in the field of Thermodynamic Properties of Solid Solutions: Solid solutions have not received the intensive study given to gaseous and liquid solutions, no doubt because accurate experimental data for solid solutions are more difficult to obtain. However, solid solutions are simpler in theory than liquid solutions, and the possibility of a simple theoretical interpretation of crystalline solid solutions is a strong incentive for their study.

Investigations of binary solid solutions of inorganic salts by the "method of the third component" are in progress. and preliminary results at low temperatures have been obtained on some isopolymorphous systems containing argon by means of measurements of sublimation

pressures.

The very limited amount of information and misinformation available in the literature suggests that many binary systems exhibiting complete miscibility may be described as both "symmetrical" and "regular." For alkali-metal halide systems with miscibility gaps above room temperature, both theory and experiment lead to a law of corresponding states for the solid solutions.

### Personnel

Sabbatical Leave: Professor David N. Hume was on sabbatical leave during the fall term at Woods Hole Oceanographic Institution. Professor Carl W. Garland was on sabbatical leave during the spring term at the University of California at San Diego. Professor John S. Waugh was on leave of absence during the spring term at the Max Planck Institute, Heidelberg, Germany.

Appointment: Professor John Ross was appointed the Frederick G. Keyes Professor of Chemistry.

Award: Professor Dietmar Seyferth received the Frederic Stanley Kipping Award in organosilicon chemistry from the American Chemical Society.

Visiting Professors: The Department was privileged to sponsor a series of lectures with funds provided from the Arthur D. Little Memorial and Karl Pfister Visiting Professorships. The Arthur D. Little Visiting Professor was Professor Ronald Mason, from the University of Sussex, who presented a series of lectures entitled, "Transition Metals and their Interaction with Polyenes and other Organic Ligands," "The Stereochemistry of and Electron Distribution in Transition Metal Complexes—Crystallographic, E.S.C.A. and Theoretical Studies," "Some Very Recent Developments in Diffraction Studies of the Structures of Surfaces and Liquids." The Karl Pfister Visiting Professor was Professor Christopher Foote from the University of California at Los Angeles who presented a series of lectures entitled, "Singlet Oxygen: Importance in Organic and Biochemistry," "Novel Olefin Oxidation Chemistry."

GLENN ALLEN BERCHTOLD

## Department of Earth and Planetary Sciences

The close of the academic year finds the Department in good spirits for a number of reasons. Research support from outside sources has risen to a record volume approaching $2.5 million. This increased activity stems from the improved Federal level of spending for science, but also because the Department covers a number of fields which are growing at a faster rate, such as oceanography, earthquake prediction and control, and environmental research. The total teaching load in the Department has increased about 50 percent in the last four years. The number of graduate students has increased by 10 percent, but the number of graduate students taught has increased by 35 percent. The number of declared majors in the Department has increased to 65, which is a record for recent years. The number of graduate students who have been admitted and who have accepted admission will increase the Department's graduate enrollment by 20 percent over the current year. With all of this activity the administration has provided the Department with additional space consisting of some 5,000 square feet in Building 24. Thus, as a result of support by the administration and Federal agencies and the vigor of the field as expressed by student interests and the Department's ability to place its graduates, the Department seems to be in a healthy position.

Numbers are not everything and growth by itself is not necessarily beneficial. The Department believes that the quality of its undergraduate and graduate educational programs has improved

significantly. Subject offerings have been reviewed from the point of need, quality of teaching, and appeal to students; they have been modified when found lacking. The Department has been ambitious in incorporating undergraduates in research and, currently, more than 70 undergraduates, many from other departments, are employed on its research projects. The Departmental budget for undergraduate research amounts to approximately $50,000 per year, mostly drawn from research grants and contracts.

The operation of the Joint Program in Oceanography by this Department, the Department of Meteorology, and the Woods Hole Oceanographic Institution seems to be going well. Applications were received from 115 prospective students for admission to the program; ten were accepted. The Wallace Observatory, a teaching and research center in astronomy under the cognizance of Dean Robert A. Alberty and staffed by this Department and the Department of Physics, is available for students at M.I.T. interested in the planets and the stars from either a professional or amateur point of view.

## Research

Some interesting results came this year from an array of current meters placed on the continental slope of the ocean. These current meters functioned as an internal wave antenna and permitted the first determination of the wave number spectrum of internal tides in the deep ocean. It was found that the internal tide is a primary sink for the energy of the surface tides. Thus, the tidal forcing may provide a significant fraction of energy required to mix the ocean vertically, since the internal tide must be dissipated partially in the open sea.

A highly precise analytical method for the determination of barium in seawater was developed. The precision of $\pm 0.7$ percent makes barium, with an average concentration of $15.10^{-6}$ grams per liter, the best determined trace element in the ocean. Extensive work is being done to apply this method to samples collected on the forthcoming International Decade of Ocean Exploration cruise, GEOSECS.

This year saw the successful inauguration of an undergraduate research group which is studying the geochemical aspects of four New England rivers. The program involves 10-20 students from several different disciplines 12 months per year, and is funded by NSF for the summer of 1972. The goals of the continuing study are to gather geochemical data on a long-term basis in order to identify the principal geochemical controls on these rivers. As understanding increases, the Department expects to develop accurate theoretical models to demonstrate the importance of critical parameters.

Ocean floor basalts cored in the deep-sea drilling project have been studied. For the first time the Department is learning about older ocean floor basalt which is now located far from the axial portions of oceanic ridges. Petrological and geochemical studies of basalts as old as Jurassic provide evidence that implies surprising chemical uniformity of Atlantic ocean floor basalt throughout the whole period of opening of the Atlantic Ocean basin.

The identification of matching structural and age provinces, matching stratigraphy and manganese horizonds, and other geological features in the older Precambrian Shield of West Africa and the Guayana Shield of South America suggest that these two regions have not been separated by great distances prior to the latest separation, which formed the Atlantic Ocean. The fact that a Pan-African thermotectonic belt was developed between these two regions in late Precambrian times raises the possibility that other Pan-African belts can be formed by *in situ* processes that do not involve plate motions and subduction zones.

Research into the Mossbauer Effect in minerals at high pressures has demonstrated for the first time that ferric ions in certain minerals (notably alkali amphiboles to date) are reduced to two-valent iron at high pressures. These results have important implications in geochemical studies of the mantle, and suggest that iron and other transition elements exist in

low oxidation states in the earth's interior.

An important contribution to the Apollo program has been to demonstrate for the first time that three-valent titanium occurs in the lunar pyroxenes. This has been accomplished by direct measurements of the absorption spectra of the pyroxene crystals in the visible region. This result conforms with findings by other groups that rocks on the moon crystallized under conditions of low oxygen fugacities.

New data on the far-field displacement spectra from earthquakes appears to require that large earthquakes and small ones obey fundamentally different physical laws. Detailed theoretical models of the fracturing process during earthquakes have given a better understanding of the controlling parameters during fault rupture and help to bridge the gap between the studies of rock mechanics and of seismology.

Pores and cracks in several rocks, as directly viewed with a new technique, have a shape that suggests an origin early in the history of these rocks. Thus, behavior in the laboratory may be a reliable indication of behavior in the earth's crust, for electrical resistivity, permeability, or other properties which depend on microporosity.

Radar observations of Mars, taken in June-November, 1971, at the Haystack Observatory (operated by M. I. T.), have yielded a high-resolution map of the surface heights and scattering properties of that planet within the band $14^{o}$ to $22^{o}$ south latitude. Where the signal was sufficiently strong, relative heights could be determined for elements of the surface with a precision approaching 50 meters. Values for the dielectric constant to the surface were found which varied between 2 and 5, the lower values possibly being associated with accumulations of surface dust many meters thick.

Radar echoes were detected in March and April, 1972, at the Arecibo Observatory which resulted from two successive round-trip traversals of the Earth-moon path. Using this technique, the reflecting properties of the Earth as viewed from the moon may be determined and compared to the characteristics of other planets as viewed from Earth.

The photographic plate has been the most commonly used two-dimensional detector of telescope images for almost 100 years. During the past five to ten years, a variety of electrooptical devices have been discussed as supplements or replacements of photography in astronomy. The Department has developed a two-dimensional integrating vidicon photometer which is especially well suited for many types of astronomical observations.

During the past year, a study of the chemical processes occurring in the primitive solar nebula has resulted in a successful a priori calculation of the densities of the terrestrial planets and the larger satellites of the outer planets. The densities of these bodies are calculable from general considerations of chemical equilibrium between condensates and a gas of solar composition in which the temperature decreased smoothly with distance from the sun. No ad hoc processes for random compositional variations or metal-silicate fractionation are needed to explain the observed densities. A number of specific strong predictions regarding the bulk chemical compositions of the planets also are derivable: for the Earth, a sulfur-rich core and a chondritic potassium abundance seem unavoidable. Theoretical considerations, experience in metallurgical systems containing silicate plus sulfides plus metal, and preliminary laboratory experiments all suggest that a large proportion of the Earth's potassium content may reside in a sulfur-rich outer core, thus providing a very large heat source in the core.

Observations of pulsar NP0532, made while the sun passed near the line of sight from the Earth to the pulsar, have been used to determine the density of the solar corona. In the region from 5 to 20 solar radii, the density found by this new technique is only one-half the

value which usually has been inferred using the rather ambiguous visible-light and radio scattering techniques. The pulsar measurements also show that the solar wind is still being accelerated at 10 solar radii, contrary to other previous measurements. Simultaneous radio scattering measurements, also using NP0532, showed that coronal density does not always increase with increased scattering. A decrease in coronal density at high solar latitudes was found to accompany the reduction of solar activity in 1971, but little change was noted at low latitudes. New information on the pulsar and on the density and radio scattering properties of the interstellar medium also has resulted from this program of observations.

A novel method of Earth based radio tracking was used to track the Apollo 16 Lunar Rover on the surface of the moon with 30-meter accuracy. Signals received simultaneously from the Lunar Module and Rover were compared to eliminate effects of the atmosphere and ionosphere and any drift of the receiving system, and signals received simultaneously at different sites were compared to eliminate effects of transmitter instability. Using the same technique, observations of the Apollo Lunar Scientific Experiment Packages are being made which are expected to yield an order of magnitude improvement in man's knowledge of lunar libration.

## Personnel

Leave of Absence: Professor M. Gene Simmons returned from a year's leave of absence, during which time he served as chief scientist at the Manned Spacecraft Center in Houston, Texas.

Appointments: John G. Sclater has accepted an appointment as an associate professor and will join the Department July 1. His main field of interest is marine geophysics and geology; he comes here following rich experience at the Scripps Institution of Oceanography. John S. Dickey, Jr. also will join the Department as an assistant professor of petrology. He currently is finishing up a research associateship at the Geophysical Laboratory of the Carnegie Institution in Washington, where he has become a specialist on the use of the electron microprobe in geochemical and petrological problems. Prior to this, Professor Dickey had extensive field experience in Europe and New Zealand. After the completion of a National Science Foundation Postdoctoral Fellowship, Sean C. Solomon joined the Department as an assistant professor of geophysics. His interests cover the structure and composition of interiors of the Earth and the moon, the physics of materials as applied to geophysics, and geophysical experiments on the sea floor.

Visiting Professors: This year, the Department enjoyed the presence of Professor E-an Zen of the U.S. Geological Survey and Professor Ronald Shreve of U.C.L.A. Professor Seiya Uyeda of the University of Tokyo, a marine geophysicist, has been visiting the Department for the spring term and will remain at M.I.T. next fall.

Retirement: Professor Harold W. Fairbairn, who has been at M.I.T. since 1937, retires at the end of this academic year. His varied background in petrology and geochronology, his strong concern for professionalism among students, and his willingness to participate on Department committees will make his departure a painful one for the Department.

Professional Activities: Professor William F. Brace was elected to the American Academy of Arts and Sciences. Professor Frank Press was named president-elect of the American Geophysical Union.

FRANK PRESS

# Department of Mathematics

## Curriculum

Attempts were made this year to strengthen further efforts in undergraduate education. An Undergraduate Mathematics Committee was established and Professor Arthur P. Mattuck was appointed its first chairman. In conjunction with this, a new Undergraduate Mathematics Office was opened to provide centralized and enlarged facilities for all information connected with undergraduate subjects and the activities of undergraduate majors. One of the first actions of the new Undergraduate Committee was to increase the bachelor's degree requirements from six mathematics subjects to eight, while liberalizing the subjects which can be used to fulfill the requirements. The ongoing work of the Committee will deal with the stimulation of new subject offerings and the improvement of teaching, particularly in subjects with a large out-of-course enrollment.

The Department has continued to revise and develop its undergraduate curriculum. The modular format for 18.01, Calculus, which was begun on an experimental basis last year, was adopted this year as a permanent part of the program. The flexibility which it provides for students to proceed at their own pace has been greeted enthusiastically by them. The version of freshman calculus which Professors David J. Benney and Harvey P. Greenspan instituted last year to emphasize the applied mathematics point of view grew in size in 1972, and also received a very positive student response. Professors Frederic Y.-M. Wan and David G. Schaeffer offered supplementary subjects on the use of the computer in calculus and differential equations. Professor Victor W. Guillemin continued his work on the revision of 18.961, the basic undergraduate differential geometry subject. His revision has placed increased emphasis on geometrical concepts and intuition, and will lead to a new textbook on differential topology. Professor Elliott H. Lieb offered a new subject, 18.254, Mathematics of Quantum Mechanics. The lectures, dealing with such topics as basic Hilbert space methods, attracted an unusually large number of graduate students from fields such as chemistry and physics. Professor Michael J. Fischer offered, jointly with Professor Albert R. Meyer of the Department of Electrical Engineering, a new workshop in the analysis of algorithms. Its purpose was to provide an opportunity for students to do individual research on the evaluation of algorithms, using theoretical and empirical methods. During the year, discussions were begun within the Department about the intellectual breadth of graduate programs. The discussions will continue into next year and deal with the role of teaching experience in graduate education, as well as the possibility of requiring knowledge of the history of mathematics or knowledge in both pure and applied mathematics.

## Research

The following is a small sampling of mathematical research going on in the Department during 1971-72.

Professor Lieb is pursuing research in statistical mechanics and other parts of mathematical physics. In joint work with Lebowitz he showed the existence of the thermodynamic limit for Coulomb systems. He is attacking the existence of correlation functions and the limit problem for positive charges fixed in a lattice, both of which are essential for the application to real matter. He has obtained some results of physical significance by using the theory of analytic functions of several complex variables to show that, above its critical temperature, the free energy of an Ising ferromagnet is analytic in the magnetic field.

Professor Daniel B. Ray continued his work with Professor Isodore Singer on torsion. If W is a compact oriented Reimannian manifold and K is a smooth triangulation of W, they have asked how one might describe analytically the Reidemeister-Franz torsion of K. Their

candidate, which they call analytic torsion, involves the zeta function for appropriate Laplacians. They have proved it to be a manifold invariant and present some suggestive evidence that it is the combinatorially defined torsion of K. In the case of a torus of one complex dimension, the analytic torsion has been expressed explicitly in terms of classical theta functions.

Professor Bertram Kostant is continuing his basic work on generalized Fourier transforms, which grew out of his quantization theory, the polarization of a symplectic manifold. In application to the representation theory of Lie groups, the point was that the representation was independent of the polarization. This appeared in the work of Harish-Chandra, Kivellov, and Auslander-Kostant. In fact, the independence of polarizations has nothing to do with groups. What appears to be the case is that, given two polarizations of a simplectic manifold, there is a transformation taking sections of the line bundle constant along sections of one polarization into sections constant along the other. In Euclidean space, this specializes to the usual Fourier transform. The continued study of the generalization has some very exciting prospects. It will encompass, for example, Hörmander's recent theory of the propagation of singularities for differential operators.

Professor Michael Artin has had as one of his projects during the year an analysis of Brauer-Severi schemes associated with maximal orders in a division ring over an algebraic surface. In the case of quaternion algebras, he and Mumford had earlier obtained some results. For arbitrary rank $n^2$, one obtains a good degeneration of the Brauer-Severi scheme at smooth points of the ramification curve, by considering the space parametrizing left ideals of rank n. Professor Artin is particularly interested in the two associated schemes at singular points of the ramification curve.

Professor William G. Strang completed this year his book An Analysis of the Finite Element Method. The subject is one of intense interest in numerical analysis, because of the success in practical engineering calculations of the finite element method. It is a technique which was created and brought to maturity by structural engineers; it is an instance of the classical Rayleigh-Ritz-Galerkin method, with piece-wise polynomials as trial functions.

The theory has led to an extremely fruitful interaction between the calculus of variations, approximation theory (including splines), and numerical methods--all with a view to explaining the success of the method and proposing improvements. In fact the collaboration between engineers and numerical analysts is one of the most encouraging and satisfying aspects of the work. It has led to a large number of new problems, significant to the engineers and at the same time sufficiently well posed for a mathematician.

## Personnel

Appointments: There have been four new appointments to the faculty this year: Assistant Professors Moshe Israeli, John W. Morgan, Alan Needleman, and Joel H. Spencer. Associate Professors Richard M. Dudley and Harold M. Stark have been promoted to the rank of professor, effective July 1, 1972.

Leaves of Absence: Professors Alberto P. Calderon, Willem Van R. Malkus, and Irving E. Segal were on leave for the academic year, and Professors Seymour A. Papert and Isadore M. Singer were on leave for part of the year.

Visiting Professors: Professors Donald Kreider of Dartmouth College and Nirmala Prakash of Indraparastha College, Delhi, India, were visiting professors during the year.

Professional Activities: Professors Malkus and George W. Whitehead were elected to the National Academy of Sciences, and Professor Gian-Carlo Rota was named a fellow of the Los Alamos Scientific Laboratory.

Other Activities: Professor Hartley Rogers was active in Institute affairs during the year. He served as chairman of the M.I.T. Faculty. In addition, he chaired the Special Task Force on Education, whose recommendations for three basic changes in the focus and organization of education at M.I.T. were adopted by the faculty.

Finally, the Department is pleased to report that Professor Franklin P. Peterson has been appointed chairman of the Pure Mathematics Committee, replacing Professor Daniel Ray, who ably filled this role for three years and is now returning to full-time mathematical activities.

KENNETH M. HOFFMAN

## Department of Meteorology

The past year has witnessed some increase in the educational and research activities of the Department of Meteorology. The number of graduate students in September, 1971, was 52 (as predicted in last year's report), and this same number is expected in September, 1972. Eleven doctorates and seven master's degrees were granted in the period September, 1971 - June, 1972, maintaining the higher-than-average level typical of the past three years. Six of the doctorates were in physical oceanography, comprising a major fraction of the eight doctorates awarded in the earth sciences portion of the Joint Program with the Woods Hole Oceanographic Institution. That program seems to have leveled off, at least momentarily, with about 42 students expected in September, 1972. The Department has continued to attract excellent applicants; two of the three new National Science Foundation (NSF) fellowship recipients in atmospheric science in the country will be among its new students in September, and its second-year students garnered four of the seven third-year NSF renewals granted in atmospheric science and oceanography. The Department also has continued to receive one of the highly competitive fellowships awarded by the University Corporation for Atmospheric Research.

Undergraduate instruction by the Department has increased, most notably in a new subject, Meteorological Aspects of Air Pollution, taught in the fall term by Professor James M. Austin, and in renewed interest in Synoptic Meteorology I, as 19 undergraduates registered for 19.43. An average of 35 undergraduates is estimated to make some use of the sixteenth-floor synoptic laboratory in each of the two terms. Next year Professor Reginald E. Newell will join with Professor John M. Edmond of the Department of Earth and Planetary Sciences in presenting a new undergraduate subject, entitled Cycles in the Ocean and Atmosphere, in which the formation, path, and destruction of trace substances will be analyzed.

Job opportunities for the Department's graduates have continued to hold up. Although civil service openings have been temporarily frozen since last September as part of the Federal government's economic plan, the continued expansion of meteorological and oceanographic research is expected to open up these and other opportunities in the coming year. Dr. Robert White, head of the National Oceanic and Atmospheric Administration, last January presented an analysis of job opportunities to the annual meeting of the American Meteorological Society. His conclusion is that the present rate of graduate education in meteorology in the United States is compatible with the expected growth of research, development, and operational practice in this field.

The two major new programs entered on by Department staff a year ago are flourishing. The Mid-Ocean Dynamic Experiment, conceived of by Professor Henry M. Stommel (with Professor Robinson of Harvard University) to explore the role of large transient eddies in the ocean circulation, has been funded as part of the International Decade of Ocean Exploration, and 15 institutions now are involved in preliminary data studies and theoretical considerations of the

design of the instrumental array. The actual "experiment" is planned as an intensive study in the spring and early summer of 1973 in a limited region, several hundred kilometers on a side, located south of Bermuda. Professor Dennis Moore, temporarily on loan to the Department from Nova University, has been acting as executive officer of the program. Professor Erik L. Mollö-Christensen's participation in the Sea Grant financed study of Massachusetts Bay is focusing this summer on an intensive study of the currents, temperature, and chemical distribution in the bay. An important aspect of this work is the design of intelligent data-handling methods and sensors.

Both of the above projects are clearly related to "environmental" problems -- the large mid-ocean eddies have time-variable currents which indirectly affect the long-term dispersion of material in the deep ocean, and the Massachusetts Bay study has obvious implications for coastal pollution problems. On the meteorological side of the Department, the research group organized by Professor Newell, which previously has studied the motion of radioactive trace substances in the stratosphere, is expanding its interest to explore the possible influence of supersonic transport operation on the ozone layer in the stratosphere. Professors Ronald G. Prinn and Norman A. Phillips and Doctors Derek Cunnold and George J. Boer also are participating in this study for the Department of Transportation.

These research examples illustrate how many problems of considerable scientific interest in atmospheric and marine science have practical implications, and it is the Department's view that this is the proper method for university faculty staff and students to participate in the application of physical science to human problems. This philosophy is consistent with a report, The Atmospheric Sciences and Man's Needs, issued in late 1971 by the National Academy of Sciences. After reviewing the problems and possibilities in atmospheric science, the report lists four objectives "for the Nation":

1. To extend the capability for useful prediction of the weather and atmospheric processes;
2. To contribute to the development of the capability to manage and control the concentration of air pollutants;
3. To establish mechanisms for the rational examination of deliberate and inadvertent means of modifying weather and climate; and
4. To reduce substantially human casualties, economic losses, and social dislocations caused by weather.

The report also emphasizes the importance of basic research in these objectives. Similar studies for marine science (e.g., Marine Science Affairs, third report of the National Council on Marine Resources and Engineering Development, 1969) contain equivalent implications about oceanography. As an example of other Departmental work in this direction, a doctoral thesis by M. S. Tracton under the guidance of Professors Austin and Frederick Sanders was able to establish the conditions under which the numerical prediction model used by the National Meteorological Center failed to predict cyclone development because of an insufficiently realistic treatment of precipitation in large cumulus clouds and thunderstorms. Dr. Tracton received the Department's annual Rossby Award for this work.

Dr. John V. Evans, director of the Thomson incoherent back-scatter radar facility at the Millstone site of the Lincoln Laboratory, was appointed a senior lecturer in the Department. He is the project director for an NSF sponsored planning study to build a new Thomson scatter facility near the U.S.-Canadian border. This observational tool is particularly valuable for probing the average and diurnal wind, temperature and ion distributions in the regions from 100 to 500 kilometers above the surface of the earth, where the thermal equilibrium and almost uniform composition of the lower atmosphere give way to the more complicated kinetic and physical effects present in the upper atmosphere. Significant results to date which are of interest to more classical meteorological theorists include a demonstration that the solar semi-diurnal tide behaves quite differently than predicted by existing tidal theory for this region.

A much smaller observation facility (but perhaps of more direct interest to local Massachusetts residents) was established in August, 1971, by the National Meteorological Service on the roof of Building 24. This is a radiosonde facility which uses slow-rising balloons to determine the temperature and wind structure in the lowest layers of the atmosphere for use in pollution alerts for the Boston area.

Professor Newell has spent the year on sabbatical leave in England and Germany, where he is studying problems of climate change. The year was also marked by the formal retirement of Senior Research Associate Alan Bemis. Although Mr. Bemis recently has not been involved in regular Departmental activities, his participation and leadership in the early application at M.I.T. of radar to meteorological problems represented an important contribution to the Department and to meteorology in the nation.

NORMAN A. PHILLIPS

## Department of Nutrition and Food Science

The total funds available to the Department for research activities increased slightly, and current prospects are for continued modest growth in overall support. The number of graduate students in the Department has remained unchanged, but the total number of qualified applicants for graduate student status has increased.

Two large interdepartmental grants have been awarded, one a National Science Foundation (NSF) RANN program grant for enzyme studies, and the second a National Institutes of Health (NIH) grant for research in arteriosclerosis.

Although the total volume of research is increasing, individuals and fields of research are affected disproportionately. This is lamentable in certain areas of food science where NIH support is decreasing or even phasing out and makes alternative support even more important. Industry does not seem to be in a position to provide significant support to the Department, but it is clear that the Department continues to make a substantial contribution to industry through its graduates as well as through faculty time and research results. A recent major effort to obtain endowment support from industry for an Underwood-Prescott Professorship of Food Science has been brought to completion.

### Undergraduate Program

There has been an increasing interaction of Department faculty with undergraduate education at M.I.T. In the fall term of 1971-72, some 146 undergraduates registered for subjects of instruction in the Department, and 196 were registered for subjects in the spring term.

In Nutrition and Food Science Projects Laboratory, 20.02, six students were registered in the fall term, 24 in the spring term, and indications are that there will be about 50 students registered this fall, with the subject being renamed Laboratory in Applied Biology and being given a different format.

A major mechanism for undergraduate participation in the Department is provided by the Undergraduate Research Opportunities Program administered by the Education Research Center at M.I.T. through department coordinators. This program had an enrollment of 34 students in the fall term and 56 in the spring term.

In addition to the above programs and subjects, some faculty members of the Department participated in the Environmental Measurements Projects Laboratory, 20.03J, which is an experiment in interdisciplinary environmental education. During the last two years, about 20 undergraduates have participated in the program.

Even though the present enrollment in the undergraduate Course VII-2 program (nutrition and food science) is small, a significant number of faculty members serve as freshman advisors, undergraduate advisors, and advisors in the premedical program at the Institute, present freshman seminars, and supervise Bachelor of Science thesis research.

Five subjects were tailored for and offered during the January Independent Activities Period. In addition, one subject entitled How Much to Eat? Of What? And Why? was offered by several graduate students in the Department.

As an alternative to two undergraduate life science options for the Department, one in Nutritional Biochemistry and Metabolism and one in Food Science and Technology, an alternative program called Applied Biology has been proposed and should become effective in the fall. This has the advantage of encompassing some degree of specialization in any of the degree areas of the Department and avoids any implication that the undergraduate program involves excessive degree of specialization.

## Graduate Program

The graduate teaching program in nutritional biochemistry and metabolism has been reorganized with a new core curriculum which began during the current academic year. The curriculum is centered around specific course work in mammalian biochemistry and metabolism and an expanded subject in mammalian nutrition.

Major modifications have also taken place in the nutritional biochemistry and metabolism doctoral examination, with the first day of the written examination being of a general nature, and the second part of the written examination focusing more directly on the student's area of interest.

In food science and technology, several subjects have been completely revised, and these changes, particularly in those subjects involving laboratories and in those at an undergraduate level, still are being revised at the present time.

A new subject entitled Food Marketing, 20.68, was presented in conjunction with Dr. Gordon F. Bloom of the Sloan School of Management, was well received by the students, and will be offered in alternate years.

## Conferences, Symposia, and Summer Courses

On October 19-21, 1971, the Department hosted the International Conference on Nutrition, National Development, and Planning under the sponsorship of NIH, Agency for International Development, IBRD (the World Bank), and the Association for the Aid of Crippled Children. The conference was a pioneering one and brought together over 400 nutritionists, planners, economists, and politicians from 53 different countries for the purpose of understanding the role of nutrition in national development and the alternate strategies available for preventing malnutrition in developing countries.

On September 23, 1971, as part of the Ninth Annual Underwood-Prescott Memorial Lectureship, a symposium on "Food Processing and Engineering for the 1970s" was held with an attendance of 325 food scientists, industry executives, and students.

A successful, well-attended International Conference on Fish Protein Concentrate was held on June 6-8, 1972. This conference focused in a realistic manner on the present status and future prospects for fish protein concentrate for human feeding.

Three one-week summer school programs were held during the summer of 1971 with a total attendance of 122 persons from industry, government, and academia. Four one-week subjects are planned during the summer of 1972. These are: Enzymes and Their Use in

Analysis and Clinical Diagnosis under the direction of Professors Samson T. Jacob, George Wolf, and Jean-Pierre Flatt; Fermentation Technology under the direction of Professor Daniel I. C. Wang; Advances in Dehydrated and Intermediate Moisture Foods under the direction of Professors Samuel A. Goldblith and Marcus Karel; and Advances in Human Nutrition Knowledge under the direction of Professor Vernon R. Young.

### Personnel

Promotions: Promotions within the Department include Research Associate Maria C. Linder to Assistant Professor of Physiological Chemistry; Ernst R. Pariser to Senior Research Scientist; Research Associate Michael C. Archer to Assistant Professor of Food Chemistry; Dr. William G. Thilly to Assistant Professor of Food Toxicology; and Dr. Charles E. Kimble to Assistant Professor of Food Microbiology.

Appointments: New appointments include Alan D. Berg, Visiting Professor of Nutrition; Dr. Charles J. Kensler, Visiting Professor of Pharmacology; Dr. Ernesto Pollitt, Associate Professor of Growth and Development and field director of the Epidemiological Study of Malnutrition in Greater Boston (NUCAM Project); and Dr. Dieter List, Visiting Associate Professor of Food Chemistry under the Faculty Exchange Program sponsored by the Ford Foundation and the Technical University of Berlin.

Resignations: Faculty resignations include Professors Phillip Issenberg and Roland Davies.

Faculty Awards: Professor Marcus Karel was elected a fellow in the Institute of Food Technologists, one of the six selected this year.

On May 17, 1972, the faculty committee responsible for the James R. Killian, Jr. Faculty Achievement Award announced that this honor would go for the first time to Professor Nevin S. Scrimshaw. He will have the title of Killian Award Lecturer for 1972-73.

The endowment goal of $600,000 for the Underwood-Prescott Professorship of Food Science was reached in late May. On May 25, 1972, President Jerome B. Wiesner announced that Professor Samuel A. Goldblith will be the first occupant of this chair. This professorship, which is the first in the country in food science, was funded by a gift from the Underwood Company which was matched by M. I. T.

NEVIN S. SCRIMSHAW

## Department of Physics

The past year has seen a continuation of the somewhat austere state of the physics profession that was mentioned in the last Departmental report. This is almost certainly responsible for much of the present movement of students away from physics, as reflected in the numbers of undergraduate students electing physics as a major. The number of graduate students in the Department also decreased slightly, but this could be attributed entirely to shortage of research support, rather than to lack of qualified applicants. The numbers of degrees awarded during the year were 107 Bachelor of Science, 13 Master of Science, and 56 Doctor of Philosophy -- less than last year but considerably more than in 1970.

The instructional programs of the Department have been carefully reviewed as to content and organization. The biggest single change was to replace the standard recitation-quiz format in the main freshman subjects, Physics I and Physics II, by a more personal tutoring-testing system involving extensive use of undergraduate tutors. The biophysical version of introductory physics has attracted increasing numbers of students, and its curriculum has been extended to include third- and fourth-term components. Student and faculty participation in the Undergraduate Research Opportunities Program has continued to increase.

During the Independent Activities Period in January, 1972, the Department was well represented by both faculty and students. The program included 24 seminars, 6 workshops, 6 field trips, and a lecture series entitled, "Frontiers in Physics."

## Research

*Astrophysics*

In X-ray astronomy, the year was marked by the successful operation of cosmic X-ray survey experiments on the satellite OSO-7 (launched September, 1971) and by observations of hard X-ray sources in the southern sky, using the largest balloon ever used for scientific purposes. A soft X-ray survey of the Cygnus region also was carried out by rocket.

Very-long-baseline interferometry (VLBI) has continued to be a major effort, involving cooperative research with the Smithsonian Astrophysics Laboratory, the Naval Research Laboratory, and the Crimean Astrophysical Observatory. Synchronized measurements between the Soviet observatory and the Institute's own Haystack radiotelescope showed the radio source W 49 (apparently a water-vapor maser) to have an angular size of about 0.0003 arc seconds.

Radiofrequency spectroscopic studies (at Haystack and at Kitt Peak) of the interstellar medium have revealed a number of lines from methanol, originating either in the Orion nebula or in the galactic center. Emissions from several water-vapor masers associated with infrared stars have been also observed and their time-variations studied.

In theoretical astrophysics, work has continued on the spinar model of quasars, with encouraging links to observational facts, such as the radio and optical emissions of the radio galaxy Cygnus A. The supernova model of the Gum nebula has been further developed to include radio and perhaps also X-ray emissions resulting from transient heating of the interstellar gas by supernovae.

In the field of plasma astrophysics, experimental and theoretical studies on the solar wind and related phenomena have been continued. The shape of the Earth's bow shock and the form of the earth's magnetopause have both been mapped to about 100 Earth radii downstream. Waves and discontinuities in the solar wind are understandable as shock waves and as outwardly propagating Alfven waves. Direct measurements of the angular momentum lost by the sun to the solar wind show that the effect is large enough to slow the sun's rotation significantly within its lifetime. Continued theoretical studies of the Alfven waves suggest that their high-frequency components could be the sole driving force of the solar wind.

Significant progress has been made on a theory of the aurora, agreeing in numerous respects with observational details of the phenomenon.

*Experimental Nuclear and High-Energy Physics* *

The Department's program in these areas continues to be vigorous and varied, despite restrictions on funding. The Department's low-energy program has concentrated on nuclear transitions inside solid matter (yielding information about both the nuclear states and the field strengths inside solids); analysis of short-lived, high-spin states of nuclei produced by heavy-ion collisions; X-ray spectra from highly ionized atoms formed in heavy-ion collisions; and structure of nuclei near closed shells, studied after nuclear excitation by $\alpha$-particles.

In the medium-energy range, the main achievement was the successful operation of the electron linear accelerator at Middleton, Massachusetts; the first beam of energy greater

* The research programs in both experimental and theoretical nuclear and particle physics have, as usual, been under the aegis of the Laboratory for Nuclear Science.

than 100 MeV was achieved on April 4, 1972, just three days before the official opening of the installation and its dedication. The Department's medium-energy group is concentrating on the preparation of the accelerator's experimental facilities, in close cooperation with a newly organized national users' group, while phasing out its program of using electron and photon scattering (at the 100 MeV electron accelerator at the National Bureau of Standards) to study charge distributions and shape functions of ground-states and excited states of light- and medium-weight nuclei.

The Department's high-energy research makes use of all available accelerators in Europe and the U.S.A. (including two experiments accepted at the National Accelerator Laboratory). Observations of "deep-inelastic" electron-neutron scattering exhibit the phenomenon of "scaling" previously found in electron-proton scattering, but scattered intensities are considerably less. Studies have also been made of neutral products from interactions of protons with antiprotons and charged pions. Tests of vector-dominance theory through photon induced processes have continued.

The bubble-chamber group (PEPR) has developed an important new technique (the "prism plot") for dynamical analysis of complex elementary-particle interactions involving up to five or six product particles.

The above experimental activities are described in more detail in the separate report of the Laboratory for Nuclear Science, included in the Provost's section.

*Nuclear and Particle Theory*

The activities of the Center for Theoretical Physics have continued in the pattern of recent years. Rather than detail the progress on many different fronts, this report concentrates on a few outstanding items.

In the field of elementary particles, a very important new start has been made on a renormalizable unified theory which includes both electromagnetic and weak interactions, and permits for the first time a calculation of such phenomena as electron-nuclear scattering in an unambiguous way.

In the field of strong interactions, attention has been given to the theory of scaling, which first made its appearance in the analysis of the M.I.T.-SLAC deep inelastic electron scattering experiment. (It states that asymptotically the probability for these processes depends on certain dimensionless ratios.) The Regge-pole models predict scaling for the strong interactions, whereas Regge cuts would imply a violation. Recent experiments at CERN indicate that it does in fact hold in this context, which raises problems of self-consistency in the theory.

In nuclear structure theory, work has continued on the use of a phenomenological density-dependent Hamiltonian to relate properties of finite nuclei to the basic nucleon-nucleon interaction. The now well-known solutions for infinite nuclear matter have been used as a starting point that would allow the very short-range nuclear forces to be taken into account. A complete fundamental theory of nuclei now seems to be feasible.

The statistical theory of nuclear reactions (largely developed at M.I.T.) has been generalized so as to take into account the many-channeled features of nuclear reactions and to satisfy time reversal invariance. This theory has a wide applicability not only to nuclear reactions but to many reaction processes which involve the production of many possible finite productions -- e.g., chemical reactions and elementary particle processes at high energy. It is gratifying that many of the methods developed by nuclear theorists at the Center have been put into use by both chemists and particle theorists.

This year marked the start of an exchange program with the theoretical center at the University of Torino. It has been very successful, and the Department hopes to continue with that program for the next few years.

*Solid-State, Laser, Plasma, and Atomic Physics*

The research in these areas has, in general, continued in the directions reported last year. The scattering of laser light from second-sound waves in liquid helium has been observed, and should lead to detailed information about the $\lambda$-transition. Molecular beam experiments have led to the production and study of Van der Waals molecules such as Xe-K and Hg-Cs. Work in solid-state theory suggested a novel form of difference-frequency spin resonance in semiconductors (subsequently observed at Bell Laboratories); the process has promise as a source of far-infrared radiation.

In quantum electronics, work has continued on precision frequency measurements using metal-oxide-metal point-contact diodes. A recent development has been the production of tunable infrared radiation from the mixing of laser and klystron signals in these diodes. The high transmission of " zero-degree" pulses through strongly absorbing media has been demonstrated. Some success also has been achieved in the development of uni-directional laser amplifiers.

Work at the Francis Bitter National Magnet Laboratory includes research in magnetism, superconductivity, magneto-optics, and environmental problems. The separate report from this laboratory should be consulted for a full survey, but one highlight is the design of an X-ray laser ($\sim$100 eV) based on population inversion for a 2p-1s transition in low-Z targets.

In plasma physics the ALCATOR project (involving the Departments of Physics, Electrical Engineering and Nuclear Engineering, and the Magnet Laboratory) continues to be the main focus of the effort. Initial tests of the machine are scheduled for the fall of 1972. Work also has proceeded on the study of plasmas through ultra-high power (100 MW) TEA lasers and high-intensity, relativistic electron beams.

Work in areas of biological interest has expanded. Light-scattering techniques have been used to study sizes and shapes of macromolecules and to study the transparency of normal and diseased eyes. A major effort is now under way on the "molecular microscope," a device designed to investigate surfaces and membranes in living specimens via the study of absorbed molecules, using molecular-beam and mass-spectrometer techniques.

Finally, a set of balloon experiments on the cosmic background radiation has confirmed its $3^{\circ}$K thermal spectrum and will be extended to search for possible galactic anisotropies.

## Personnel

Promotions: The following faculty members received promotions as of July 1, 1972: to professor, Hale V. D. Bradt; to associate professor, Eric R. Cosman, Roman W. Jackiw, and John W. Negele.

Appointments: New faculty members in the Department will be Assistant Professors Kenneth Brecher, Carleton DeTar, Susan Kleinmann, and June Matthews.

Visiting Professors: Visiting faculty members during the year were Visiting Professor Arnon Dar and Visiting Associate Professors Howard H. Brown and Gabriele Veneziano.

Retirements: This year sees the retirement of Professor Robley D. Evans, who has been on the faculty since 1934. With his retirement, the management of the Radioactivity Center will be transferred to the Medical Department.

Awards: Professor Victor F. Weisskopf was the first American recipient of the Cino-Del Duca International Award for "a message of modern humanism in arts and sciences" at ceremonies in Paris on June 8, 1972. Professor John G. King received one of the Harbison Awards of the Danforth Foundation in recognition of distinguished contributions to teaching.

Harry Anderson received one of the two James N. Murphy Awards presented to employees whose "spirited contributions to the Institute family have won a place in the hearts of students." Samuel A. Cohen, a graduate student in the Department, was awarded the 1972 Goodwin Medal for his outstanding work as a graduate teaching assistant.

VICTOR F. WEISSKOPF

# Graduate School

During the year the Graduate School Office has devoted major attention to the problem of graduate student support necessitated by the marked curtailment of government graduate fellowship programs. To alleviate this crisis, temporary support for a few outstanding students has been provided by the Institute in the form of Sloan Research Traineeships, but in the long run it is imperative that more research assistantships and fellowships from outside sponsors be established for graduate students.

At the same time, a study has been made of typical student expenses for housing, food, tuition, medical fees, books, clothing, travel, etc. From this study a "cost of living planning kit" was developed and sent to every student accepted for admission in September, 1972. These students are finding this brochure of great help in planning for graduate study at M.I.T.

In the academic field, the Committee on Graduate School Policy (C.G.S.P.) has devoted its attention to new fields of study, particularly interdisciplinary areas pertinent to the solution of societal problems. Interest in the growth in size of the Graduate School has been replaced by concern for improvement in the quality of graduate education. A study made by the American Council of Education places M.I.T. in the top six institutions in the country for quality in graduate fields in which it is rated. M.I.T. headed the list of U.S. institutions indicated as first choice for graduate study by students awarded National Science Foundation Fellowships for 1972-73.

## Enrollment

Although the Graduate School has grown rapidly in the years following World War II, this growth began to level off in 1965 when it approached 3,200 students. An all-time peak of 3,395 was reached in 1969. Since that time growth has remained fairly stable and in 1971-72 total enrollment of regular graduate students was 3,250. This figure is expected to remain about the same in 1972-73. In addition to regular students, there were 330 special graduate students registered who were not pursuing a formal degree program. A total of 1,307 Master's, Engineer, and doctoral degrees were awarded during the past year (see Table II).

The cause of the stable graduate enrollment typical of recent years is not due to the imposition of rigid quotas by M.I.T., but relates rather to external factors. Most important of these is the marked decrease (now only one-third of the former number) in Federal fellowships for graduate study. Other sources of financial support have also decreased while tuition and the cost of living have precipitously increased. The slight decline of graduate enrollment also reflects the general recession in the economy which is marked by a high unemployment rate. The lack of job opportunities in aerospace and related industries, particularly, contributed to a decreased enrollment of graduate students in such departments as Aeronautics and Astronautics and Physics. An expected upturn in the economy, with improved employment opportunities for professional people, should bring greater student interest in pursuing graduate study in the coming years.

The decrease in the growth of the Graduate School is not unique to M.I.T., as most private

universities have suffered decreases in graduate enrollment of up to 25 per cent. By contrast, public universities have continued to grow at a very modest pace. The reasons for the relative stability of M. I. T.'s graduate enrollment, compared with other private universities, are being studied. Of probable significance are: 1) the special efforts M. I. T. has made to find additional graduate financial aid; 2) the excellent record of M. I. T. in finding jobs for its graduates; 3) the greater relevance of some of M. I. T.'s graduate programs to societal needs; and 4) the improvement of M. I. T.'s international reputation for graduate study. Despite the favorable past record, strenuous efforts in the future will be needed to maintain the present level of graduate student enrollment as costs continue to escalate.

## Fellowships, Scholarships, and Assistantships

The impact of reduced Federal financial support for graduate education has become evident during the past year. In the last three years the number of Federal fellowships has declined from 700 to 300 and a further decrease is expected. At the same time, there has been a modest decrease in both research and teaching assistantships (see Table III). Industrial fellowships have also decreased while foundation fellowships have shown a modest increase. The net effect of these changes is reflected by the fact that 85 per cent of the graduate student population receives either full or partial assistance (at least tuition support) compared with 90 per cent a few years ago. To assist students who require partial help in meeting their expenses, the Office of Student Financial Aid has made available government insured loans arranged through the students' banks. These loans, as useful as they are in a financial emergency, cannot be expected to take care of all the costs of a student's education, which typically add up to $35,000 for a doctoral degree. Hence, it will be essential in the future to devote major effort to finding funds for additional assistantships and fellowships. If these efforts are not successful, the Graduate School at M. I. T. might well shrink in size as students move to the state universities where the costs of education are much lower.

## New Graduate Programs

Problems of society have become so complex and multifaceted that no single discipline can address itself adequately to their solutions. Of special interest to M. I. T. have been problems of the metropolis, pollution, environmental control, ecology, malnutrition, overpopulation, health care systems, oceanography, energy, and natural resources. To deal with such problems, a systems approach is essential, since too often new knowledge acquired in the laboratory never gets applied to the needs of mankind. To deal with such interdisciplinary matters, there is a need for professionals who are broadly trained rather than for the specialist who knows little beyond a narrow area of science or engineering. A new breed of graduate student is now enrolling who is deeply concerned with the problems of society and dedicated to working out their solutions. Hence the Graduate School has devoted major attention during the past few years to setting up interdisciplinary programs concerned with these problems. One of the most successful is oceanography, established in 1968 as a joint degree program with the Woods Hole Oceanographic Institution. Departments at M. I. T. directly involved include Meteorology, Earth and Planetary Sciences, Biology, and Ocean Engineering. While most students work on doctoral programs, the latter Department also offers the Engineer degree. Some 52 graduate students were enrolled in the joint programs during the past year, spending part of their time at Woods Hole and the remainder taking subjects at M. I. T. During the year, ten students earned graduate degrees in this program.

Operations research is a well established doctoral program which involves collaboration among the Sloan School of Management and several departments in the School of Engineering, as well as the Departments of Physics and Mathematics. During the past year, the

operations research program has been expanded to include a Master's degree program in which a number of students are already enrolled.

A joint doctoral program involving the Departments of Urban Studies and Planning and Economics was approved three years ago but to date only a few students have enrolled. In view of the fact that this program presents a sound and important approach to the study of certain problems of the city, it should grow in the near future.

For some time certain engineering departments, such as Chemical, Electrical, and Mechanical, have had cooperative Master's degree programs with certain industries. These cooperative efforts with industry have been very important and successful and are being further developed by M. I. T. In particular, the program in electrical engineering has been expanded to enroll more students and to include new cooperating industries, as well as the Massachusetts General Hospital.

A new interdisciplinary program in health sciences and technology was introduced during the past academic year. It is operated jointly with the Harvard Medical School and is designed for students, primarily from Harvard University, Radcliffe College, and M. I. T., who wish a medical education with a strong basis in science and technology. Students enroll in special preclinical subjects at M. I. T. and, in addition, may elect regular M. I. T. graduate subjects. Training in clinical medicine is taken at the Harvard Medical School and its affiliated hospitals. This program leads to the M. D. degree from Harvard Medical School. In September, 1971, the first 25 students were enrolled in this experimental program and 25 more have been accepted for September, 1972.

Closely allied with the Program in Health Sciences and Technology is an interdisciplinary doctoral program in biomedical engineering. Work in this field is designed primarily for students in the School of Engineering and is supervised by a standing committee of the faculty appointed by the Dean of the Graduate School. Biomedical engineering students take subjects in the life sciences, as well as engineering subjects at M. I. T., plus certain subjects at Harvard Medical School. Research may be conducted in the Boston hospitals, as well as at M. I. T. Some 130 graduate students are enrolled in this flourishing doctoral program.

Far along in the planning stage but not yet finally approved by the C. G. S. P. or the M. I. T. Faculty, is an interdisciplinary program leading to the degree of Environmental Engineer. In addition to subjects in several departments of the School of Engineering, students will be required to take certain subjects in science, economics, political science, and management which have special relevance to the problems of environmental control. Students working toward the degree of Environmental Engineer will receive special guidance from a faculty committee to be appointed by the Dean of the Graduate School.

## Minority Graduate Students

During the past four years, strenuous efforts have been made to increase the number of minority (particularly black American) graduate students. This undertaking involves recruitment efforts, special tutorials, and counseling, as well as fellowship support for these students. The Chancellor and the Committee on Equal Opportunity, as well as the Graduate School Office, have been involved in this program. As a result of these efforts, the number of black American students has increased from 6 in 1967 to 87 in 1971 and is expected to number approximately 100 in the fall of 1972. In the past year, attention has also been devoted to other minorities with the result that there are now on campus one American Indian, four Chicano, and six Puerto Rican graduate students. Special funds have been allocated by the M. I. T. administration which provide tuition scholarships for all entering minority students. In addition, most departments have been able to make available

tuition scholarships for continuing students and, in most cases, partial or full stipends for both beginning and continuing students.

The results of this program for minority graduate students have been quite gratifying not only in terms of the rapid increase in numbers but also with reference to the academic performance of these students, some of whom have already received graduate degrees. To further strengthen and expand the program for minority students, an Assistant Dean will be added to the Graduate School Office staff in the coming year.

## Women Graduate Students

The increase in living accommodations, as well as the emphasis on graduate degrees with social relevance, has made M.I.T. a more attractive place for women to undertake graduate study. In addition, traditionally male-oriented fields are beginning to offer excellent employment opportunities to women. As a result, the number of women graduate students has risen from 200 in 1967 to 300 in 1971. Financial aid for women is, in general, comparable to that for men. This increase in number of women graduate students has not resulted from any direct recruitment, and it is felt that special efforts by the Graduate School could increase the number of outstanding women students appreciably. During the coming year, considerable attention will be devoted to all aspects of graduate education for women at M.I.T.

## Foreign Graduate Students

A special study of graduate education of foreign students was made by Ronald S. Stone, Executive Officer of the Graduate School, who was assisted by the Foreign Student and Student Financial Aid Offices. This study showed that 28 per cent of the graduate student population is foreign, many with special problems. Financial support, including loans, for foreign students is particularly troublesome and will need attention. The C.G.S.P. will continue this study of foreign graduate students and should make recommendations for changing and improving the education of such students during the coming year.

## Graduate Student Affairs

During the past year the Graduate Student Council (G.S.C.) has played an important and responsible role in both academic and extracurricular matters pertaining to graduate students and has served as a sounding board for graduate student opinion. Graduate student representatives have served on most of the Institute's committees, including two on the C.G.S.P. During the year, many students from the G.S.C., as well as other graduate students, have been guests (with speaking privileges) at C.G.S.P. meetings. The Muddy Charles Pub operated for graduate students, faculty, and their guests by the G.S.C. has become a congenial and important social center on campus. At its monthly meetings, the Council has discussed with administrators and faculty many problems concerning graduate life at M.I.T. including campus medical care, housing, and cost of living. In September, the G.S.C., in collaboration with the Dean for Student Affairs and the Dean of the Graduate School, sponsored the annual orientation and reception for new graduate students. This will be repeated in September, 1972, with the price of admission being to fill out a questionnaire asking why the students chose M.I.T. for graduate study. A similar questionnaire has already been mailed to students accepted by M.I.T. asking their reasons for refusing admission.

## Graduate Housing

A new graduate student apartment complex, Westgate II, housing 400 single students will be ready for occupancy in the fall of 1972. This new building will help to alleviate the shortage

of campus housing for graduate students. At the same time, Westgate II will make possible a renovation of Ashdown House. Closing half of Ashdown House for the next two years will permit only half of it being available for residency during the time of remodeling. Therefore, half of the Ashdown residents will be housed in Westgate II or in off-campus apartments.

## Graduate Placement

The depressed economy and resultant unemployment has raised problems of finding jobs for recipients of graduate degrees. The Director of Placement, Robert K. Weatherall, is also Assistant Dean of the Graduate School in which post he can be especially effective in helping to solve the placement problems of graduate students. Placement has been especially difficult in such fields as physics, chemistry, and aeronautical engineering and in some cases students have had to accept postdoctoral fellowships or temporary jobs instead of permanent positions in their specialties. Even in these trying times, however, M. I. T. graduate students have been remarkably successful in finding jobs and very few of our recent graduates are actually unemployed. By comparison, M. I. T.'s placement record is appreciably better than most institutions.

## The Outlook for Graduate Education

Serious problems in graduate education will continue during the next few years. With the development of new interdisciplinary programs, M. I. T. might suffer less from the recession than most private schools. Enrollment at M. I. T. is expected to remain constant or decrease slightly while the quality of graduate education improves further. Hopefully, an increase in the number of women and minority graduate students of high merit on the M. I. T. campus will also be realized in the near future.

IRWIN W. SIZER

TABLE I-A
Graduate School Quotas and First-Term Registration, 1971-72

| | All Schools | Engineering | Science | Architecture and Planning | Humanities and Social Science | Management |
|---|---|---|---|---|---|---|
| Quota | 3,475 | 1,670 | 1,006 | 221 | 278 | 300 |
| Registration | 3,250 | 1,560 | 899 | 227 | 251 | 313 |

TABLE I-B
History of Quotas and Registration, All Schools, 1967-71

| | 1967 | 1968 | 1969 | 1970 | 1971 |
|---|---|---|---|---|---|
| Quota | 3,342 | 3,342 | 3,420 | 3,443 | 3,475 |
| Registration | 3,344 | 3,274 | 3,395 | 3,296 | 3,250 |

TABLE II
Graduate School Statistics, 1971-72

| Advanced Degrees Conferred: | B. Arch.* | M. Arch.** & M.C.P. | S.M. | Engineer | Sc.D. | Ph.D. | Total |
|---|---|---|---|---|---|---|---|
| September, 1971 | 3 | 12 | 162 | 16 | 14 | 140<br>3(WH) | 350 |
| February, 1972 | 1 | 8 | 157 | 33 | 27 | 84<br>2(WH) | 312 |
| June, 1972 | 18 | 30 | 381 | 66<br>2(WH) | 28<br>1(WH) | 117<br>2(WH) | 645 |
| Total | 22 | 50 | 700 | 117 | 70 | 348 | 1,307 |

* B. Arch. changed to M. Arch. as of June, 1972
** M. Arch. changed to M. Arch. A.S. as of June, 1972

| Graduate School Registration: (Includes Regular and Special Students) | Summer 1971 | Fall 1971 | Spring 1972 |
|---|---|---|---|
| School of Engineering | 938 | 1,714(40)* | 1,605 |
| School of Science | 684 | 952(116) | 919 |
| School of Architecture and Planning | 36 | 290(66) | 275 |
| School of Humanities and Social Science | 147 | 278(47) | 272 |
| Sloan School of Management | 92 | 346(19) | 317 |
| Total | 1,897 | 3,580(297)** | 3,388 |
| Regular Students | 1,864 | 3,250*** | 3,076 |
| Special Students | 33 | 330 | 312 |

* Numbers in parentheses indicate number of women graduate students
** 2,691 = U.S. and Canadian students
889 = Other nationalities
*** 99 minority group students were registered as regular graduate students during the fall term of 1971

TABLE III
Summary of Graduate Financial Assistance for 1971-72

| | | |
|---|---|---|
| Total regular graduate students | 3,250 | |
| Federal fellowships and traineeships | 621 | (19%) |
| Graduate student staff | 1,445 | (44%) |
| Industrial and foundation awards | 152 | ( 5%) |
| M.I.T. endowed and budgeted funds | 220 | ( 7%) |
| Students sponsored by external sources | 322 | (10%) |
| Total awards | 2,760 | (85%) |

TABLE IV
Graduate Student Support

The sources of support for most of the M.I.T. graduate students in 1971-72 are listed. However, a single table is an incomplete reflection of the total picture, since support shifts constantly throughout the academic year in accordance with changing status, early termination of degree program, the draft, and so on. Because of the statistical problem created by this constant change, this table was devised to present a representative "snapshot," in effect. For purposes of this count, a full award was considered as at least full tuition support during the fall term 1971.

Fellowships and Traineeships awarded by M.I.T.:

| | |
|---|---|
| Atomic Energy Commission Traineeships | 8 |
| National Defense Education Act Traineeships | 80 |
| National Science Foundation Traineeships | 96 |
| National Institutes of Health and other Health, Education, and Welfare (HEW) Traineeships | 167 |
| Industrial and Foundation Fellowships | 107 |
| M.I.T. Endowed and other Fund Fellowships | 130 |
| NASA Stipend/M.I.T. Endowed Fellowships | 6 |
| Sloan Research Traineeships | 90 |
| Environmental Protection Agency Traineeships | 6 |
| TOTAL | 690 |

Fellowships awarded by sponsors to M.I.T. students:

| | |
|---|---|
| Atomic Energy Commission Fellowships | 14 |
| National Science Foundation Fellowships | 215 |
| National Institutes of Health and other HEW Fellowships | 19 |
| National Aeronautics and Space Administration International Fellowships | 4 |
| Housing and Urban Development Fellowships | 2 |
| Woodrow Wilson Fellowships | 3 |
| Woodrow Wilson Dissertation/M.I.T. Endowed | 2 |
| Hertz Foundation Fellowships | 27 |
| Danforth Foundation Fellowships | 5 |

TABLE IV
Graduate Student Support (continued)

| | |
|---|---|
| U. S. Department of Labor Fellowships | 3 |
| Ford Foundation Minority Fellowships | 8 |
| Environmental Protection Agency Fellowship | 1 |
| TOTAL | 303 |
| Student Assistantships - Research | 964 |
| Teaching | 481 |
| TOTAL | 1,445 |

Sponsored Students

Many students are known to be receiving support from employers and sponsors. The following reflects Bursar's billings for tuition to such employers and sponsors, who presumably provide stipends to such students by private arrangements.

| | |
|---|---|
| U. S. government agencies | 196 |
| Industry and foundation | 67 |
| Foreign countries and international programs | 59 |
| TOTAL | 322 |
| TOTAL students considered to have received full awards -- academic year 1971-72 | 2,760 |

Partial awards, loans, and miscellaneous programs -- tuition or lesser amounts.

Individual student support in many cases is derived from partial awards ranging from $100 to $3,000 each. In many cases, an accumulation of partial awards and/or loans provides a student with essentially complete support. As a result, the number of such partial awards does not reflect the number of student recipients.

| Partial Awards | |
|---|---|
| M.I.T. Endowed and Special Budget | 75 |
| Industrial and foundation | 34 |
| TOTAL | 109 |

| Graduate Loans | No. of Loans | Total Amount |
|---|---|---|
| M.I.T. Administered | | |
| National Defense Loans | 253 | $434,685 |
| Graduate Loan Fund | 139 | 211,501 |
| M.I.T. Guaranteed Loans | 38 | 49,400 |
| TOTAL | 430 | $695,586 |
| Non-M.I.T. Guaranteed Loans | 95 | 130,985 |
| TOTAL Regular Loans | 525 | 826,571 |
| Short-Term Loans | 163 | 59,337 |
| TOTAL LOANS | 688 | $885,908 |

TABLE V
Federal Awards to M.I.T. Graduate Students

| | Atomic Energy Commission | Housing and Urban Development | National Aeronautics and Space Administration | National Defense Education Act | National Science Foundation Fellowships | National Science Foundation Cooperative | National Science Foundation Traineeships | Total |
|---|---|---|---|---|---|---|---|---|
| 1951-52 | | | | | | | | |
| 1952-53 | | | | | 48 | | | 48 |
| 1953-54 | | | | | 46 | | | 46 |
| 1954-55 | | | | | 51 | | | 51 |
| 1955-56 | | | | | 61 | | | 61 |
| 1956-57 | | | | | 64 | | | 64 |
| 1957-58 | 26 | | | | 64 | | | 90 |
| 1958-59 | 35 | | | | 92 | | | 127 |
| 1959-60 | 43 | | | 4 | 100 | 39 | | 186 |
| 1960-61 | 39 | | | 14 | 102 | 40 | | 195 |
| 1961-62 | 39 | | | 25 | 152 | 42 | | 258 |
| 1962-63 | 34 | | | 29 | 165 | 44 | | 272 |
| 1963-64 | 35 | | 15 | 32 | 178 | 53 | | 313 |
| 1964-65 | 41 | | 30 | 28 | 206 | 58 | 79 | 442 |
| 1965-66 | 27 | | 45 | 40 | 207 | 55 | 114 | 488 |
| 1966-67 | 30 | | 45 | 72 | 231 | 8 | 132 | 518 |
| 1967-68 | 45 | 3 | 39 | 131 | 230 | | 146 | 594 |
| 1968-69 | 36 | 7 | 24 | 137 | 245 | | 151 | 600 |
| 1969-70* | 33 | 11 | 9 | 132 | 262 | | 143 | 590 |
| 1970-71* | 25 | 7 | | 80 | 288 | | 141 | 541 |
| 1971-72* | 14 | 2 | | 80 | 227 | | 96 | 419 |

This table denotes awards offered, and differs from table IV which denotes awards accepted by registered M.I.T. students.

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.

* Not included in table: 3 NASA International Fellowships, 19 NIH Fellowships and 167 NIH Traineeships for 1971-72.

# Dean for Institute Relations

Looking back over a three-year period, the Institute and particularly the office of the Dean for Student Affairs first had to respond to "revolution" and then to the anomie and despair which followed. There have been significant changes in the concerns of the undergraduate students at M. I. T. Appropriately there have been shifts in emphasis and in organization of the Office of the Dean for Student Affairs and in the Athletic Department. Dean J. Daniel Nyhart and his staff report on these developments in the following pages.

In reviewing this period, five themes emerge. Probably most important for the role of the Dean for Student Affairs has been the accelerated move away from an in loco parentis model of student support services toward a catalytic, facilitating, decentralized organization of the Dean's Office. Such a shift did not occur without attendant strains, though these were more than offset by the ability of members of the Office to respond to a greater range of students with more diverse needs. The minority students and women undergraduates found aspects of their experience at M. I. T. wanting, and with support from Deans James J. Bishop, Nanette L. Smith, Emily L. Wick, and many others, sought to improve their situation. The students living in the fraternities and in the dormitories found that their previous agreement on norms of behavior no longer held. For example, this past year they had to find a new consensus as the basis for their ground rules for coeducational living.

Dean Nyhart has moved the Office of the Dean for Students Affairs and the Athletic Department to a program budget. This has made possible a more accurate assessment of our limited resources. The Talbot House is now self-supporting (within the funding provided by Laurence Rockefeller), and the subsidy for a number of the activities has been reduced without a significant drop in the services provided. These and other economies were the direct result of the new budget process.

There have been reforms in the judicial procedures used by the Faculty Committee on Discipline. Dean Nyhart worked closely with both students and faculty and was able to maintain significant credibility and concern for the evolving judicial process against great odds. This accomplishment only accentuates the need for a continuing review and improvement of these procedures. Dean Carola B. Eisenberg, the present Committee on Discipline, and the Committee on Educational Policy clearly will need to carry forward the dialogue that Dean Nyhart began.

The Dean's Office has looked continuously for the educational opportunities inherent in the students' experience in their living groups, in their classrooms, and in their other activities, and has sought to help students to integrate these often disparate experiences. Strengthening the housemaster-tutor program pursuant to Dean Richard A. Sorenson's initiative is an excellent illustration of this effort. The relevance of the program for the coming decade, however, needs to be reexamined.

We have all learned many lessons from living in and through this period. To be sure, these are not unique to M. I. T.; they do, however, have particular force on our campus, rooted as it is in a science/engineering context.

Six years of relatively calm, though significant, educational innovation was brought almost to

a halt during the highly visible, dramatic events of 1969 and 1970. The bitter aftermath of this period meant that the momentum of the preceding years almost was stalled. A year later we now begin to move again.

Dehumanization, a major threat inherent in the confrontations two years ago, still faces us today. Ironically, the explicit intent is often to "humanize" the participants. However, an educational encounter also can dehumanize both students and faculty, depersonalizing them by routinized and bureaucratic procedures. A grading system can become a wall between professor and student when it is constructed on the professor's scorn and the student's shame. This only suggests that psychological exploitation in the classroom may be more subtle than that practiced in the streets. When it occurs, it usually extends over a far longer period of time. These walls, the barriers between individuals and groups, have been a major focus of attention of the Dean for Institute Relations.

One of our educational goals has been to facilitate the student's working closely with his or her professor in a real, not contrived, shared experience where they could come to know the expectations and assumptions each held about the other. Many have worked hard on this goal for M.I.T.'s education. A number of changes have occurred in the past ten years; U.R.O.P. is an excellent example. One generalization stands out: the danger of dehumanization is lowest where we develop rapid and reliable educational interaction between students and faculty and highest where we fail to do this.

Short- and long-term education planning was set back by the interruptions of 1969-70. Those programs that did develop -- three significant educational experiments, for example -- went ahead in spite of, not because of, protests. Those reforms which were directed at the fundamental reward structure -- at reducing classroom confrontation, as pass/fail grading was -- began before the political crisis and continued to be considered seriously.

The rate of educational and institutional change in sum was slowed down rather than accelerated by the turmoil. Dehumanization increased to the point where faculty and students for a time scarcely could communicate effectively with one another. A new, constructive conversation has begun, and all signs point to its continuation.

BENSON R. SNYDER

# Dean for Student Affairs

This year saw considerable accomplishment in new programs designed to help specific groups of students make more of their M. I. T. learning experience: students headed toward law, medicine, or education; undesignated sophomores; minorities; women; students transferring to M. I. T. from other colleges; and students in undergraduate seminars. Substantial improvements also were made in the processes by which members of the M. I. T. community gain access to Kresge, Talbot House, and community facilities as a whole. Serious planning and commitment for needed new or restored facilities in athletics and housing progressed during the year, as the homework which led to the past two Visiting Committee meetings began to bear fruit. The living environment program drew solid support from students, faculty, and administration, as efforts to increase the involvement of faculty and graduate residents in the life of the Institute houses began to have their impact and to gain deserved recognition. Finally, transitions and changes in Dean's Office personnel and in faculty residents took place which, I believe, will give the Dean's Office a new opportunity for its members to work (together and with the Institute community as a whole) toward improving the quality of students' overall learning experience at M. I. T.

Before detailing these highlights more fully, I would like to convey some observations on the past year. These lead to the conclusion that, in the coming years, the Institute will be challenged as rarely before to provide its students with the kind of education they feel they need for the professional and personal challenges of the tumultuous final quarter of this century.

Students are facing their education with more serious concern than they did during the heyday of activism, when turning the world over was more important than turning over the pages of their problem sets. There is also an increased seriousness of commitment among those few students who remain interested in the political scene.

However, the major new element I have found during this past year is the spreading and deepening of young people's disillusionment with the vitality and workability of many of the basic institutions of this country -- governmental, corporate, and educational. The frustration over the Vietnam war is even wider and deeper than it was two years ago. Most students doubt that we are getting out and doubt nearly everything they are told by the government about our getting out. Thus a major cleavage exists between the young and the older anti-war people on campus, who do believe the war is "winding down" and who, therefore, find themselves able to sublimate somewhat their feelings about the escalated air war. Disaffection with the values of corporate society has been described so often; one can only comment that discussions with students confirm those descriptions. Closest to home, many thoughtful students express a general unhappiness with their educational experience.

In sum, it is no longer revolutionary to be disillusioned or cynical; it is commonplace. So much so, that today's real revolutionaries may well be those who are committed to change, but have found some part of the system with which they can identify sufficiently to provide themselves a framework for their commitment.

Inevitably, the general disillusion with the country's institutions influences students' university life. It is a major contributor to the malaise that besets many students today. It

also contributes to another phenomenon which in turn feeds the malaise. As they increasingly doubt their surrounding institutions, students are asking more questions of their own identity.

Thus the return to serious study has been accompanied by a real concern among students as to who they are, why they are here, and where they are going. The acuteness with which students are sensing their own maturing, and how their university experience relates to the process of maturing, is a part of the malaise. It not often is articulated as such, but it is there.

Their quest for maturing is closely related, I believe, to the perspective in which students hold their university and their university experience. To them that experience is a whole one. The university must take some responsibility for, or at least give recognition to, the maturing processes, if students are to give the university the recognition it seeks from them. Therefore, the university will find that it must not divorce the formal academic effort from the growth which takes place outside that framework.

This unity of education sought by students today raises structural questions of administration. The Dean's Office, traditionally concerned with the environmental side, must move still closer to the academic life of the Institute. Academicians must be ready to respond to their students' quest for maturity. The Dean's Office members are alert to these issues, and are eager to continue attacking the obstacles to their resolution. In this respect, I believe the Office is in good hands as it receives its new Dean, Dr. Carola B. Eisenberg.

Dr. Eisenberg assumes the Deanship amidst a transition of personnel which has accelerated during the past year. In addition to my moving into the Chancellor's Office, several other staff changes took place. Some came at the end of 1970-71 and were reported in last year's report.

During the summer, Jon Hartshorne took up his duties as the Dean's Office representative in the Student Center. The improvements in the processes of allocation of the very limited special facilities throughout the Institute have been accomplished largely through Mr. Hartshorne's diligence and pervasive good nature. It is with pleasure that I announce his promotion to Assistant Dean, as of the new academic year.

Susan P. Haigh joined us in October from the Career Planning and Placement Office to open the Preprofessional Office. It provides a new structure for advising students interested in medicine, law, or education. She will move with me into the Chancellor's Office.

Late this spring, Nancy J. Wheatley, Class of 1970, joined the Office from the Educational Research Center, to work with Dean Peter Büttner on the Freshman Advisory Council and undergraduate seminars. Ms. Wheatley assumes responsibilities ably carried out by Joe LaBreche, who received his master's degree in management during the year, and by Alice Bailey, who followed her husband as he graduated from M. I. T. and reported to the Air Force.

In mid-October, Professor Emily L. Wick indicated her desire to return to full-time teaching and research, after seven years in her role as Associate Dean. She made the switch as of January 1, 1972. Dean Wick has meant so much to so many students, that it is impossible to say more than a thank-you from all her associates and students and to wish her a joyous return to her primary pursuit. After a very thorough and rewarding search, Anne Ellison, now working in the Educational Research Center and on the completion of her doctorate in M. I. T. 's Department of Philosophy, was asked to join the Office to work with women students and to share generally in "deaning" and counseling responsibilities.

Two other major changes took place in the counseling wing. Dean Nanette Smith will be moving to Providence, Rhode Island in August, and Dean David Waite Yohn is returning to

the ministry as minister of the West Barnstable parish at West Barnstable, Massachusetts. Both have contributed to the education and life of many M. I. T. students during the short two years they were here. We wish them full success in their new lives.

Dean Harold L. Hazen retires this year after five successful years as Foreign Study Advisor, and many more before that as Dean of the Graduate School and Head of the Department of Electrical Engineering. His advice to and support of M. I. T. students studying overseas or elsewhere in this country capped a truly outstanding life of service to the Institute and to the cause of education. Professor William N. Locke and Dean Robert J. Holden will share in an expanded program of assistance to students who plan study outside of M. I. T.

Finally, I am moving to the Chancellor's Office to work on charting the course of law-related studies at the Institute and to work with a subset of M. I. T.'s students and faculty -- those with interests in the "preprofessional" fields -- to help those students make a richer and more relevant learning experience of their M. I. T. education.

J. DANIEL NYHART

## Student Counseling and Advising Systems

"Student counseling," as practiced at M. I. T., is very largely a matter of learning to listen to what a student says (or does not say) in his own words, of trying to help the student see what options are open to him, and of trying to help the student verbalize his feelings. It is not an attempt by laymen to practice psychotherapy. M. I. T. students do not expect anyone else to solve their problems; they imply, perhaps without saying so, that they expect to solve them themselves, and that talking matters over with another person is one of the ways they can do so.

It is in some ways inaccurate to give the title "student counseling" to only one section of the Office. Every member of the Dean's Office counsels students in one way or another and every counseling member does "deaning." A great deal of effective counseling is done by those members of the faculty who serve as freshman advisors, advisors to undesignated sophomores, faculty counselors for upperclassmen, faculty residents in the Institute houses, and by preprofessional advisors and many other members of the community. Counseling of the most skillful kind is provided by the members of the psychiatric staff of the Medical Department. In this connection, it is important to bear in mind that M. I. T. students quickly learn from upperclassmen that they need not define themselves as "sick" in order to consult one of the psychiatrists. Instead, they find that they can discuss any kind of problem, academic or personal, which for the moment is disturbing them.

The Dean's Office both counsels students and supports those advisory efforts directed toward specific subsets of the student population, which are reported below. During the past year, the four members of the Office devoting a substantial portion of their effort to "counseling" saw over 1,200 students in a typical month. Most of these were seen only once, although in those services directed toward particular subgroups there is a tendency to see students more than once.

The Committee on Academic Performance (C. A. P.), composed of faculty, students, and representatives from the Dean's Office, reviews at the end of each term the status of each student whose end-of-term grades indicate that he or she has not made "satisfactory" progress.

During the two terms, the C.A.P. voted the following actions:

| | January 1972 | June 1972 |
|---|---|---|
| S.B.'s Granted | 161 | 817 |
| Academic Disqualifications | 9 | 6 |
| Negotiated Withdrawals | 16 | 31 |
| Warnings | 152 | 138 |

Visitors to the Institute often are surprised to find out how much time and attention are devoted to individual students. Such decisions as the ones this Committee may need to make rest very heavily on the information and insight provided by the student's faculty advisor. Professor Ernest G. Cravalho completes a year of ably chairing the Committee.

WILLIAM SPEER

## Minority Undergraduate Students

In 1971-72, the Institute's minority student efforts, supervised by the Task Force on Educational Opportunity, devoted considerable attention toward improving ongoing activities, toward assessing the educational experiences of the undergraduate minority students and their relationship to previously adopted programs, and toward assisting minority students in making their M.I.T. learning experience a more satisfactory one. The year of evaluation and assessment contrasted somewhat with the years 1968-71, when many M.I.T. policies and programs were iniated for attracting, offering admission to, financing the education of, rendering supportive services to, and developing academic subjects about, blacks, Mexican-Americans, and Puerto Ricans.

Before reviewing these aspects, it should be noted that markedly fewer minority students enrolled in September, 1971, than had in the two previous years, in spite of intensive mailings, school visits, advertisements, conferences, and other recruitment techniques. The decline in entering black students from 59 in 1970 and 53 in 1969 to 45 in 1971 was due mainly to a smaller number of final applications. The admission standards for, and the fraction of, black applicants offered and accepting admission remained essentially the same for all three years. Undoubtedly, the causes of a general decline in the number of applicants at M.I.T. had similar effects upon the potential minority applicants.

### Ongoing Activities

Twenty-five of the black students of the class of 1975, four Spanish-speaking students, and six white students attended the academic transitional program, Project Interphase, during June-August, 1971. This program, again coordinated by Dean Bishop, made two significant changes from earlier years. To gain greater interest and value from the humanities component, an optional section using exclusively black authored and black related material was included. Both sections of humanities covered a broader socio-economic and cultural spectrum. The literature for readings, discussions, and writings consisted of novels, essays, and biographies specially chosen to focus on the issues and questions currently being raised by, and relevant to, freshman college youth.

The second change involved the inclusion in the program of an optional chemistry subject. This subject was designed primarily for Interphase students planning to major in chemistry, biology, chemical engineering, medicine, or metallurgy. The chemistry classes reviewed the fundamentals of high-school chemistry prerequisite to organic chemistry and covered those concepts of 5.41, Introduction to Structure, Bonding, and Mechanism, which are most difficult for freshmen to comprehend.

Unlike the academic record of the prior two summers of Project Interphase, all of the students who attended the program in 1971 successfully completed the three required subjects -- calculus, physics, and humanities. In addition, seven students earned six units of advanced standing in chemistry and three completed the six required examinations of 18.01, the regular fall calculus subject.

Throughout 1971-72, Deans Nanette Smith and James Bishop provided increased direct support to the black students and former Project Interphase participants. As in the previous years, introductory conferences were held with entering minority freshmen. When the freshmen evaluation forms, reports from instructors and advisors, or indications from other sources suggested that students were having academic or personal difficulties, the students were invited individually to discuss their situations with members of the Dean's Office. In the absence of a system that routinely cautions upperclassmen and their advisors about the student's status in each class, information on upperclass minority students was obtained during the term by direct communication with the students' advisors, instructors, and tutors. Very often this information came too late to be of much assistance during the term.

Dean Smith served as supervisor of the two-year-old Black Student Union tutorial program, which was used in 1971 by 60 percent of M.I.T.'s 125 black students. Although the program initially was envisioned as a supportive service for freshmen and sophomores, it was made clear this year, both by the number of students requesting help in upperclass subjects and by the number of upperclassmen in academic difficulty, that the B.S.U. tutorial program should be prepared to aid juniors and possibly seniors. Steps are under way to select upperclass and graduate students as tutors and to receive additional help from the departments to meet the needs of juniors and seniors.

Dean Smith also continued to give a series of dinner parties at her apartment for students to discuss educational, social, leadership, and creative writing issues. She worked with Karl K. Singer III, Assistant to the Registrar, on luncheons for blacks who served as freshmen advisors.

## Improving the Educational Experience

Two important events which exposed black students to careers in science, engineering, and technology occurred in the spring of 1972. "A Black Experience in Science and Technology," organized by Dean Smith, was held to broaden awareness of issues related to the conference topic, to afford M.I.T. black students the opportunity to meet black professionals, and to provide students the chance to identify some of the technical and nontechnical needs and considerations of urban communities. More than 200 people, including representatives from colleges throughout the greater Boston area and from Columbia University and Yale University, attended the two-day event on the first weekend in February, 1972. Speakers in workshops devoted their attention to the topic areas of communications, economic development, health care, and transportation.

Later in the spring, a "Career Day" was held at the General Electric plant in Lynn, Massachusetts. This was an experience which gave black students a chance to learn of career possibilities, to hear about the role of blacks in a specific profession, and to spend several hours with a professional person as he performed his job. Black students from all classes participated, but freshmen and sophomores particularly felt that this kind of experience ought to be expanded, as it can be helpful in selecting majors while at M.I.T. and in choosing paths after graduation.

Also, as part of an effort to enhance the interactions between black freshmen, upperclassmen, and graduate students, a group of students worked with Dean Smith to organize, for implementation during 1972-73, a "buddy system" for freshmen. They are trying to decide how to offer

this same service to graduate students.

Among other continuing direct efforts to aid minority students' educational experience are facilitating contacts between minority students and sources of summer and term-time jobs, discussions with individual faculty and staff members regarding their minority advisees or students, and assisting or referring students who bring educational and administrative matters to our attention. Most of these activities are very similar to those done throughout the Dean's Office, but they frequently involve more aggressive seeking out of students and a greater degree of follow-up.

## Assessment

When the Institute first began its widespread equal educational opportunity efforts four years ago, it had practically no experience in determining the academic potentials of minority students. I had only limited knowledge of the problems that would be associated with the new program. The program that developed was based primarily upon three inputs: 1) the feeling of many members of the Task Force that the range of backgrounds and personalities of black students who could succeed at M.I.T. was broader than that of whites; 2) the personal experiences of Task Force members, including black students; and 3) mixed information regarding experiences of other schools quite different in student composition and educational style from M.I.T.

Since 1968, M.I.T. has accrued six terms of experience with over 170 undergraduate black and other minority Americans. The Task Force steadily has assessed progress of minority students with the hope of determining what would be the best guidelines for recruiting, admitting, and supporting these students. Until the end of the past fall term, too limited data was available to understand the myriad factors affecting minority students' education and personal lives at M.I.T.

A substantial amount of analytical work was performed by Kenneth E. Schoman and reported to the Task Force in January, 1972. With this report, the academic performance of the 157 blacks who entered as freshmen in 1969, 1970, and 1971 has become the most carefully investigated factor of M.I.T. minority education. Mr. Schoman reported that 22 (42 percent) of the 53 blacks of the Class of 1973, in their fifth regular term, were performing excellently or satisfactorily. Approximately an equal number, 23 (43 percent), of the students either were failing or had left M.I.T. Eight (15 percent) were experiencing weak achievements. Of the 16 who were no longer M.I.T. students, only four left with nonfailing records. The record of the 59 members of the Class of 1974, in their third term (their first term with letter grades), showed that 24 (58 percent) were receiving satisfactory or better records. Nine (15 percent) were weak in their achievements. Sixteen (27 percent) were failing or withdrawn from the Institute. One term with pass-fail grades was too short a period of time to draw conclusions about the 45 black freshmen in the Class of 1975.

In June, 1972, the Class of 1973 improved slightly. An additional five students, a total of 27 (51 percent), by then were performing satisfactorily. They included two students who had satisfactory performances for the first time since entering six terms ago. The performance of the Class of 1974 blacks worsened from January to June. In January, two students withdrew from the Institute and in June, the number of voluntary or academic withdrawals or disqualifications had increased to 11 (25 percent). For the Class of 1975, just concluding its first full year at M.I.T., 33 (73 percent) of the 46 black students were performing satisfactorily, a somewhat improved record over the first-year performances of blacks in the Classes of 1973 and 1974. Those classes, after one full year, had 64 percent and 59 percent of their members with satisfactory achievements. However, the freshman class had higher percentages of black withdrawals than the two previous classes. Five members of the Class of 1975 (11 percent) withdrew following their poor performances in the first term or were required

to withdraw after their second consecutive term of failure. For the Class of 1974, 1 (2 percent) withdrew after two terms and 5 (9 percent) of the Class of 1973 were out of the Institute following the Institute following their freshman year.

Mr. Schoman's report also pointed out that the performance of blacks during their second and third years showed net downward shifts from their first year's performances. Only a few black students improved after a poor first year's record. Furthermore, the anticipated performance of the Class of 1974 in its first term of grades over that of the "pioneering" previous classes at the same point did not occur.

The overall accomplishments of these three classes of black students were considerably above what had been predicted by traditional methods. Their accomplishments substantiated the premise that more black applicants could be given a wider than traditionally used range of standardized test scores to predict safely their academic performance at M. I. T.

Notwithstanding these positive points, the general academic performance of black students produced concern and a feeling that a crisis point had been reached. The frequency of their failing performances remained much higher than was expected initially. Further, the failure rate was felt to be above what educationally and humanely can be permitted to endure. The Task Force was unanimous in its feeling that something had to be done to improve the academic situation of black students and to reduce the agonizing and long-lasting cost to those students who are unable to complete their education at M. I. T. During January and February, Institute committees, student groups, and those offices at M. I. T. most closely connected with minority student education explored at length the possible causes of, and alternative remedies for, the generally poor academic situation of black undergraduates. Responses varied according to whether or not the causes of these failures were seen to be due to the inadequacies of total resources for meeting the educational needs of minority students, to the inappropriateness of admission guidelines, or to an atmosphere and population at M. I. T. that was hostile toward and incompatible with undergraduate blacks.

The outcome of these meetings, as stated by Chancellor Paul E. Gray to Professor Leon Trilling, Chairman of the Faculty Committee on Undergraduate Admissions and Financial Aid, was: "The task force has, after extended debate, without unanimity and with much reluctance, come to the following conclusions, which we now present to you as recommendations for the admission policy to be followed in acting on applications for entrance in September, 1972:

1. The Institute should, during the present term, devise a way in which the present situation can be understood in more detail, the possibilities of more effective helping resources can be explored and developed, and the Institute's continuing commitment to educate greater numbers of black and minority young people can be implemented in the future...

2. For the next academic year only, the guidelines for admissions should be changed with the intent of not offering admission to applicants who, on the basis of prior experience, appear to have a low probability of academic success...."

The specific guidelines which grew out of Mr. Schoman's analytical studies were:

1. Admit all applicants whose grades in math and science were essentially all A's and refuse all applicants whose grades in math and science were B's or worse. (This was essentially the same guideline that was used in admitting the classes of 1973 and 1974.)

2. For those applicants with grade averages between A's and B's in math and science, the Admissions Committee should pay particular attention to the science Achievement score and consider the flexible floors for admission being in the high 500s. (This was the only significant shift from prior guidelines and practices, whose flexible floors were on the SATs and math Achievement scores.)

This recommendation was adopted by the Faculty Committee on Undergraduate Admissions and Student Aid. Although it was expected that the institution of this guideline would reduce the admitted class by as much as one-fourth, the number of black students expected to enroll in the fall will be 42, only three less than the number which enrolled in 1971.

JAMES J. BISHOP

## Undesignated Sophomores

Undesignated sophomores, i.e., those who have not chosen a major at the beginning of their second year, have, until this year, lacked intensive organization of their faculty advisors. In 1971-72, the Dean's Office gave increased attention to the concerns and implications of this group, which has grown from 58 full-time students in 1960-61 to 228 full-time students in 1971-72. At this level, undesignated sophomores constitute the largest group of second-year students in the Institute. There are presently 81 advisors, with administrative support provided by the Dean's Office (during the past year by Dean David Waite Yohn with administrative assistance from Carolyn Scheer).

The increased attention can be divided into two major components. In February, 1972, Ms. Scheer completed a study of undesignated sophomores in the class of 1973-74 which uncovered some alarming tendencies. Undesignated sophomores were found to have higher withdrawal rates than the rest of the sophomore class (3.2 percent as opposed to 1.9 percent), as well as a higher percentage of C.A.P. actions (9.2 percent as opposed to 3.8 percent) during the fall term of 1971-72.

The study also suggests that a higher percentage of undesignated sophomores go into humanities and social sciences (16.6 percent as opposed to 4.5 percent).

In December, 1971, an ad hoc Advisory Committee for undesignated sophomores was established to assist the Dean's Office and to give advice in academic matters. The Committee met first in time to consider those undesignated sophomores who were likely subjects for C.A.P. action in the 1971-72 fall term. Since that time, it has acted much as a departmental committee would act, by contacting advisors before the C.A.P. grades meetings and by screening advisors' recommendations. The Committee met throughout the spring, first to improve the mechanics of the advisory system and subsequently to explore more thoroughly some of the deeper educational issues surrounding undesignated sophomore status.

The Committee arranged with the Registrar that next year, for the first time, freshmen could select an undesignated option on the Registrar's course selection card. Also by agreement with the Registrar, registration for unspecified students, i.e., students who have yet to designate, will be handled separately from that of undesignated students. This will allow the Undesignated Sophomore Office to concentrate more fully on the needs of the undesignated students.

The Committee hopes to be able to cut the advisory system down to a core of perhaps 30 advisors from the present 81. During the discussion, and with the aid of the Scheer Report, the Committee was able to identify four distinct groups of undesignated sophomores: 1) those who

have a clear idea of what they want, but have deferred choice; 2) those who are not sure what interests them; 3) those with little academic motivation; and 4) those who are at the wrong institution. The Committee hopes to provide advisory help more along the lines of those groupings, and the general thrust in the future will be to help students make a positive departmental choice.

The Committee's plans also look toward more communication with departments and departmental advising resources, therefore -- both to keep the Committee updated on curriculum change within the departments and to provide better communication for students who are interested in designating a particular department. The Committee additionally will be working on improving academic counseling for undesignated sophomores, including communicating what specific options are available at M. I. T. Finally, it hopes to establish, with the assistance of the departmental advisors, a series of seminars about departmental majors and the careers for which they prepare students. Both faculty members and professionals in the field will be invited for an informal program and small group discussions with students.

DAVID YOHN

CAROLYN SCHEER

## The Freshman Year

Experiments with self-pacing in the basic physics subjects, 8. 01 and 8. 02; the introduction of a third experimental program, Concourse; and the faculty vote on pass/fail highlighted the academic aspects of the freshman year. Building on experiences with self-pacing, particularly in the Department of Physics and in 18. 01-18. 02, Professor Robert I. Hulsizer and members of his staff developed a series of units for 8. 01 during the fall term. Although early difficulties were encountered due to the large number of unit exams, most problems were solved by the end of the term. Professor Hulsizer considered the experiment successful, pointing, among other things, to increased student-staff interaction. The number of units was reduced in the spring term for 8. 02 in order to achieve a better balance between the frequency of exams and the scope of material covered.

The first year of the Concourse experiment was considered by the staff involved to be generally successful. In the fall, the Committee on Educational Policy (C. E. P. ) commissioned a study of the Experimental Study Group and Unified Science Study Program. Later in the year, the C. E. P. reported to the faculty that, in their opinion, both programs had made valuable contributions to undergraduate education, both as alternatives within the freshman year and for the insights they provided. The Experimental Study Group will continue basically in its present form, while the Unified Science Study Program will offer the Freshman Project Year, with students spending a portion of their year directly involved with an ongoing research group. Overall, approximately five percent of the freshman class was enrolled in these three programs.

The Committee on the Evaluation of Freshman Performance concluded its three and one-half years of study on pass/fail with the recommendation to the faculty that: 1) pass/fail be continued indefinitely, and 2) pass/no record be tried for two years. The faculty rejected the proposal for a trial of pass/no record, but voted to continue pass/fail for an additional year. The faculty also accepted a recommendation that instructors be required to note outstanding performance on evaluation forms or other records, and that departments keep sufficient records for a period of five years to be able to provide evidence upon a student's request of outstanding performance. The use of letter grades for this purpose was approved but not required.

Overall enrollment in elective subjects continued to increase. Participation in the

Undergraduate Research Opportunities Program increased, while enrollment in undergraduate seminars decreased somewhat, despite an increase in the number of seminars offered.

Summary figures are on the following page. All spring term data is as of April 3, 1972.

| | Fall 1972 | | Spring 1972 | |
|---|---|---|---|---|
| | Subject | Registration | Subject | Registration |
| Ungergraduate Seminars | 41 | 513 | 48 | 275 |
| Undergraduate Research* | 15 | 20 | 15 | 64 |
| Other Electives | 135 | 1,212 | 197 | 2,125 |
| Totals | 191 | 1,745 | 260 | 2,464 |

* UR plus special project subjects taken by freshmen.

For the second year in a row, the Independent Activities Period (I. A. P.) provided a productive and welcome break from the formal academic schedule. Although fewer statistics are available this year than last, informal reports indicate that most freshmen took considerable advantage of the many, diverse opportunities available.

Throughout the year, the Freshman Advisory Council (F. A. C.) worked with the Committee on Academic Performance to improve the procedures for reviewing freshman academic records at the end of each term. At the end of the first term, 45 freshmen received warnings from the C. A. P. At the end of the second term, 58 students received warnings and an additional 10 students were asked to withdraw for at least one term.

## Freshman Advisory Council

Recruitment efforts one year ago resulted in a record 208 advisors and 150 associate advisors during the past year. The resulting reduction in the average advisee-advisor ratio was welcome, although we fell short of our goal of being able to assign to each advisor no more than his preferred number of advisees. The largest increase in the number of advisors came not from the faculty, but from the staff, although many of these do have teaching responsibilities. The breakdown of advisors by category is as follows: 123 faculty (including 20 fall-term seminar instructors); 24 teaching staff; 11 research staff; 8 teaching assistants/research assistants; and 42 administrative staff.

During the course of the year the chairman and the executive officer met informally at least once with over 90 percent of the advisors and with approximately 50 percent of the associates. The chairman also established an Advisory Group consisting entirely of volunteers: 16 advisors, six associates, and four freshmen. The Group discussed a varied agenda at its five meetings during the year.

The Associate Advisor Program, in its fourth year, was reviewed in detail. Advisors, associates, and a sample of freshmen were polled for their opinions and a number from each group were interviewed in person. While it was acknowledged that the typical associate's role often was very limited, there was almost unanimous support for continuing the Program. Efforts will be made to strengthen the Program next year.

The practice of assigning advisees according to advisors' preferences, which often included nonprofessional interest, was continued. Advisors frequently reported that initial communications were often easier and continuing relationships more likely as a result of this practice.

Freshmen were encouraged to change advisors if an improved relationship seemed likely; approximately seven percent of the freshmen (not counting those who moved into the three experimental programs) took advantage of this flexibility.

## The Freshman Handbook

Residence/Orientation Week continued to attract the voluntary participation of large numbers of upperclassmen. Under the leadership of Rebecca Donnellan, Class of 1972, the recent trend of improved organization and execution was continued. A new program of orientation expressly for parents proved very successful.

The effort to reduce the fiscal year 1973 budget resulted in a decision to eliminate reimbursement to advisors, at the rate of $3.00 per advisee, for entertainment of their advisees. An informal pool of advisors revealed both a general understanding of the need to reduce expenditures and support for this decision. However, it is quite possible that over the years this reimbursement has become at least a token of the Institute's concern for advising and as such ought to be reinstated in fiscal year 1974 (not, of course, at the expense of actual policy changes which would be of real benefit to advisors).

Plans for the coming year include studying the advisor-advisee relationship in more depth than has been done in the past. An effort will be made to understand how effective the present advisory system is as a vehicle for student-faculty interaction and what potential the system has for improvement. The F.A.C. will also support the C.E.P. as the latter reviews freshman pass/fail in preparation for a recommendation to the faculty regarding continuance after next spring. Considerable staff time will be devoted to meeting with freshmen in a systematic way to develop a better means of assessing student attitudes toward their freshman experience and to provide more freshmen with the opportunity to be heard on matters which affect them.

## Undergraduate Seminar Program

Administrative responsibility for the Undergraduate Seminar Program was transferred to the F.A.C. Office at the beginning of the year, and the F.A.C. Chairman assumed overall responsibility for the Program. Several administrative changes were instituted, resulting in improved service to both freshmen and seminar instructors.

Compared to previous years, the number of seminars was up, while student registration declined. (Data for the year is in an earlier section on the Freshman Year.) The latter effect would appear to be due not to a decline in the quality of seminars, but rather to the apparently increasing attractiveness of other elective opportunities.

During the fall, an extensive study of the Seminar Program was undertaken to gain a current view of the seminar experience from the perspective of both the students and instructors. Questionnaires were sent to all 41 instructors and to two randomly chosen students in each seminar. Most of these individuals also were interviewed in small group sessions consisting of five to ten people. The conclusions, stated briefly, were that students and faculty alike enjoyed the flexibility and openness encouraged by the seminar format. A variety of teaching-learning styles was evident, and the principal student suggestion was that the teaching format be delineated more clearly in the written description. It also appeared that in most cases the six-unit undergraduate seminars did not represent the more intensive student-faculty interaction envisioned by the Rogers Task Force. Nevertheless, the Seminar Program as it now stands has wide support from both faculty and students. During the coming year efforts will continue to promote increased faculty involvement in the Program.

PETER BÜTTNER

## Women Students

A record 128 women students were admitted to M. I. T. in the Class of 1975. The admission of women has climbed dramatically in the last five years, as follows: 1967 -- 53; 1968 -- 65; 1969 -- 73; 1970 -- 87; 1971 -- 128; and 1972 -- 117.

With this increase, a growth in the number of women faculty, and national attention focusing on the status and role of women, there has been a marked increase in concern, discussion, and action regarding the environment of women during this year. The determination of Dean Emily L. Wick to return to teaching and research gave impetus both to the students and the Dean's Office to undertake a searching review of that environment. In December, 1971, the Dean for Student Affairs announced the intention of organizing a committee to review the environment and the required support structure for women students on campus. This committee was formed in the latter half of January under the co-chairmanship of Professor Mildred S. Dresselhaus and Paula Stone. Simultaneously, during the Independent Activities Period, Professor Dresselhaus and Professor Wick began a series of semi-weekly meetings called the Women's Forum, open not only to students but to all women members of the community. Under both these auspices, a thorough discussion of the status of women students at M. I. T. has been conducted throughout the spring term.

The Ad Hoc Committee set up under the Dean's Office reported on 11 different headings: undergraduate admissions and financial aid; admission of women to Graduate School at M. I. T.; the academic environment; Dean's Office; student activities; athletic report; housing; Wellesley-M. I. T. Exchange; Medical Department; child care; and employment.

Progress in several of these areas was made in the course of the spring term. Athletic facilities for women have been improved, the physical education requirement for undergraduates has been extended to women, and a full-time director of women's athletics has been appointed. A group from the Ad Hoc Committee met several times with the Wellesley-M. I. T. Exchange Committee for consideration of points raised regarding that Program. The writers of other portions of the Ad Hoc Report have met with appropriate faculty or administrative individuals or groups to discuss recommendations. Two student members of the Ad Hoc Committee are working during the summer on specific and concrete follow-up.

Two members of the Ad Hoc Committee joined two deans in extensive search for a new woman member of the Dean's staff. At the suggestion of the students, this search was extended to all recent women alumni of M. I. T. and to faculty wives. Over 100 resumes were received and over 30 candidates interviewed for the selection noted above.

This is only the beginning of improving conditions for M. I. T. 's women students, but with the discussion and airing of a number of concerns and viewpoints long buried, the woman student entering with the Class of 1976 will find a much more welcoming environment than has existed before.

J. DANIEL NYHART

## Preprofessional Advising and Education

The Committee on Preprofessional Advising and Education was created in response to the needs of the increasing population of students who are interested in careers in law, medicine, and education. The Committee acts to assure that mechanisms exist in each of the present preprofessional areas (medicine, law, and education): 1) to provide students with informed

counseling and guidance; 2) to monitor trends in career choices of undergraduates and to inform the faculty so that they may act to meet the changing needs of students; and 3) to discover the idiosyncratic entrance requirements of individual medical and law schools.

In its first year, the Committee has strengthened the premedical, prelaw, and preeducation programs. Three councils operate within the jurisdiction of the Committee: 1) the Education Council, chaired by Louis Menand III; 2) the Prelaw Advisory Council, chaired by Stanley M. Jacks; and 3) the Premedical Advisory Council, chaired by Bernard S. Gould.

## The Education Advisory Program

There has been a development of interest in secondary school teaching among M. I. T. students. Those who take a prescribed group of subjects now can become certified teachers in the Commonwealth of Massachusetts.

The members of the Education Council are prepared to talk with any student about his or her interests in teaching as a career, graduate study in education and teaching, and education related activities available at M. I. T. and in the greater Boston area. In addition to advising students, the Council is concerned with a wide range of education and education oriented activities at M. I. T.

## Prelaw Advisory Program

The number of students who apply to law school has increased dramatically in the past two years. A Prelaw Advisory Council has been formed to provide adequate counseling for this group. This year, 92 students and 132 alumni took the Law School Admission Test. Of the students, 69 were undergraduates and 23 were in graduate programs. Some of those who apply to law school appear interested in combining their science and engineering backgrounds with a legal education to generate new solutions to social problems.

## Premedical Advisory Program

The Premedical Advisory Council has been enlarged in response to the increasing number of students applying to medical school. There are now 24 members of the Council. Professor Gould, Chairman of the Council, wrote to 46 of the 108 medical schools in the United States that accept students from the general population, asking them to address our premedical students. Twenty-four have responded favorably to our invitation to visit M. I. T. and 13 have come already. Additionally, the pamphlet, A Premedical Handbook for the M. I. T. Student, was published in March. It answers many of the questions which students have when applying to medical school.

The new Program appears to have increased the percentage of students accepted by medical schools. The Office of Preprofessional Advising and Education processed 1, 610 applications to 106 medical schools. Of the 158 student applications, 115 or 73 percent received 267 acceptances from 69 medical schools. Of the fourth-year applicants with a grade point average of 4. 0 and higher, 86 percent were admitted to medical school, while the acceptance rate of those with 3. 9 or below was only 37 percent. The median grade point average of those students who were admitted to medical school was 4. 5. Ninety-three percent of the fourth-year students who applied to medical school were in the School of Science, and 79 percent of them majored in chemistry or biology.

Bernard Gould, Susan Haigh, and Alan Hein represented the Committee on Preprofessional Advising and Education on the Ad Hoc Committee on pass/fail. This committee examined the effect of the present freshman grading system on applicants to medical schools. The recommendation which the Ad Hoc Committee made to the faculty is essentially a restatement of the

rules and regulations of the faculty as amended in March, 1972. Recognition now can be given in terse, concrete terms by the instructor to the student who has done outstanding work. This might be a letter grade if the instructor wishes to indicate it. Grades are to be released only upon the request of the student.

ALAN HEIN

SUSAN HAIGH

## Foreign Study Office

The total of inquiries to this Office has numbered approximately 150 among students interested in a junior year elsewhere; over half of these students have been interviewed in some depth by the Foreign Study Advisor. During the current year, 19 are studying abroad, and five are studying at other institutions in this country. Eight students currently are scheduled for study abroad in 1972-73, and seven at other domestic institutions. There is no discernible reason for the change in numbers other than the inevitable statistical fluctuations.

At the graduate and postdoctoral level, the Office has received inquiries resulting in 62 interviews during 1971-72, with 20 applications through M. I. T. channels, and three to five scholarships occupied. The comparable figures for 1970-71 were 76, 21, and seven fellowships occupied.

Interest in the undergraduate Domestic Year Away is increasing substantially. Nine students became interested seriously this year, compared with three in 1969-70. At no time, however, has it developed to more than a relatively small fraction of the limit of 20 set by the faculty vote which established this program on an experimental basis.

The foreign study advising process does not lend itself to any degree of standardization or uniformity of pattern, because each student represents an essentially unique combination of background, experience, interests, motivation, and seriousness of desire to study elsewhere. The Foreign Study Advisor must explore how today's young people are thinking about their future plans, and the relation of M. I. T. experience to these plans. Relatively little specific advice is needed or desired by the individual student. As a result of self-examination of interests and background, he or she normally finds that the level of interest is insufficient to justify the substantial amount of work required to develop an acceptable program, or, on the other hand, becomes involved enthusiastically. Thus, many students voluntarily sort themselves out.

The results of an educational experience away, either abroad or domestic, are almost impossible to quantify because the benefits are so largely in expanded horizons from interaction, living, and growth in another environment and culture. It seems very clear, however, that for practically all, the experience has been very successful. Probably the greatest benefit of the entire program is the deep and impressive awareness that there are cultures, value systems, and styles of life quite different from the one the student has known, and that these justify his respect, understanding, and sympathy.

Two relatively minor roles of the Office have been as an information source center on the programs available at other institutions during the January Independent Activities Period, and as a general foreign travel information center.

HAROLD L. HAZEN

# The Living Environment

## Institute House System

Three new Senior Faculty Residents were selected during the year to fill vacancies in Burton House, East Campus, and McCormick Hall. In all three houses, the students played a primary role in their selection; this was the first time that these important personnel decisions involved students so extensively.

In Burton House, Professor James D. Bruce and his family succeeded Professor Herbert Woodson and family. Dr. Adrianus J. M. Houtsma, already a Faculty Resident in East Campus, has replaced Professor Alvin W. Drake, who served for almost seven years as the Master in East Campus. Professor Drake and his wife, Elisabeth, brought about dramatic change in the House during their years of most distinguished service. Professor Stephen D. Senturia and family are taking on the Mastership in McCormick Hall. They replace Professor Klaus Biemann and family.

The annual graduate resident (tutor) selection process was marked this spring by the effort to place significant numbers of black graduate students as tutors. Since the summer of 1971, a group of black graduate students has worked diligently with Dean's Office in this effort. It is gratifying to report that for the coming year, there will be six black tutors serving in five houses. As usual, undergraduates assisted ably in the total selection process.

A three-day workshop for all faculty and graduate residents was held prior to the arrival of the freshmen last fall. It was a most successful experience, highly valued by the participants. The idea will be continued next year in a slightly altered form, based on the suggestions of last year's participants.

This was a year of continued high retention in the Institute House System. In fact, the upward trend was remarkable in view of the rather large rate increases. Ninety-eight percent (an increase of seven percent) of the sophomores returned to the system after their freshmen year, while the return rate of juniors and seniors remained stable.

This past year has witnessed the introduction of a voluntary commons. Student response to this new option was positive, though the economics of the situation continues to be difficult. (See details in report of the Director of Housing and Dining.) In the coming year, a second house dining hall, McCormick, will be closed, an action forced by its very low use (approximately 50 students in the spring of 1972). For program reasons, this decision was made with considerable reluctance, and only after every alternative was explored with the residents of the House. We strongly hope to be able to hold the two remaining facilities, Baker House and MacGregor House.

The past year was a year of excellent student leadership. Throughout the Institute House System, the student government was consistently stronger, more active, and more responsible than at any time in recent memory. This leadership evinced itself in a number of ways, including a fine effort in planning and executing the residence section of the Residence-Orientation Week. Students also gave a superior effort for almost two months in the annual rate review process. Thanks in no small measure to their suggestions, ideas, and work, we were able to hold rent increases to a reasonable level and commons to no increase for the coming year. The efforts of the student leadership in Burton House merit special mention. In the difficult period of the first year of a new house, the leaders functioned with great

expertise and creativity without the continuity and guidance of a housemaster. The Institute is indebted to them for making the new Burton's first year a fruitful experience for all.

## The Fraternity System

The fraternities again experienced a record rush, attracting some 411 new students during Residence-Orientation Week. Rush was carried on with a minimum of difficulty and in an atmosphere of generally good relations with the Institute House System. The first good research effort of rush also was conducted by the Interfraternity Conference, and has provided the fraternities with very useful information on the rushing process.

The success of individual house programs remains relatively high, but not without problems. Tau Epsilon Phi has begun a year of rebuilding, following the essential dissolution of the chapter a year ago. Through the efforts of the Interfraternity Conference, representatives of the national fraternity, local alumni, and the Dean's Office staff, 18 young men were attracted to membership last fall. This core group, primarily freshmen, have had a good first year.

Operating costs and high accounts receivables continue to plague many houses, and the Interfraternity Conference is beginning to explore ideas for alleviating this. An overall primary objective of the Dean's Office next year will be to spend considerably more time and effort in working with fraternities, both individually and collectively.

## Facilities in the Institute House Systems *

Growth in both quantity and quality of facilities took place last year. In September, Burton House reopened after complete renovation. It has proved, as predicted a year ago, to be the system's premier facility. During the past year, the Office has worked with Baker House government on their concerns about their facilities and their relationship to the rest of the system. This effort has resulted in a regular client-team relationship, and plans were begun for minor work this fall in some Baker House public areas. The interior design services of the firm of Goody and Clancy have been engaged to assist in this effort.

At the outset of this year, a feasibility study of "restoration" of Ashdown House was begun. After an internal program review with staff and student residents, the Institute contracted with an architectural firm for the study. Following the study and related cost estimates, the M.I.T. Building Committee approved this project's commencement after final design is completed sometime in early January, 1973. This will be a 20-month, two-stage project at a cost of approximately $3,200,000. A client team of students and staff is now busily at work with the architect on the final design and program considerations of this project.

The Office also is exploring with the Planning and Housing Offices the various considerations for a new housing facility in the general Westgate area which would be designed for married student families. We anticipate that the definitive program, site, and financial planning data will be completed within the next several months.

Planning has not progressed as rapidly as anticipated in the area of undergraduate housing resources, and that is one of the most important task priorities now facing this office. Thus a major study resulting in a program for additional undergraduate housing is planned for the near future. The need for such a program remains critical in light of the projected inability to meet, under existing policies, even freshman housing demands in September, 1975.

---

* See also the Report of the Director of Housing and Dining.

### Facilities in the Fraternity System

The very significant development of the year in fraternity facilities has been the Fraternities Collaborative. After five years of extensive effort, the Collaborative (comprised of Alpha Tau Omega and Kappa Sigma) has received the Institute's approval for development on the Burton-Conner parking lot site. The Collaborative, now in final design stage, also has the M. I. T. Building Committee's approval for its initial design (pending final review) and has received financing from the Board of Allocation of the Independent Residence Development Fund. Ground breaking is anticipated in September, 1972. The project will be a visible demonstration to the community of the viability of our fraternity program and its strong future. This project also will use all current funds in the Independent Residence Development Fund. It is hoped urgently that the Fund will see a rapid redevelopment with the full cooperation of the Institute and its fraternity community.

During the past year a minor renovation project has been completed at Delta Tau Delta with Institute financing. Pi Lambda Phi is beginning a renovation project aimed primarily at increasing the degree of privacy afforded its members.

RICHARD A. SORENSON

## Student and Community Activities

The range of student and community activities continues to broaden, although the inconsistent support of the M. I. T. family has caused a number of activities to inquire searchingly into the real interests of their audiences, clients, and members. The issue presently common to all student and community activities is summarized in the recent observation of one individual: "I regularly attend the functions of the organization, but each time it seems to be a different collection of individuals." Despite this problem, there were a number of positive developments in the activity environment during the year.

The Facilities Use Committee was established to assist the Provost in responding to non-M. I. T. requests for Institute space, and to develop case law with regard to this category of facilities usage. One result has been increased communication between the various scheduling officers and the Office of the Provost. The Scheduling Officer for the Student Center Committee is a member of this Committee. Efforts have been made throughout the year to bring the various regular users of Kresge Auditorium into closer communication in order to achieve greater fairness and efficiency in scheduling. Lecture Series Committee, Dramashop, M. I. T. Community Players, the Chinese Students Club, the various musical groups, the Black Students Union, and many others all have cooperated in determining what is hopefully an equitable schedule for 1972-73.

A student committee has been formed to assist the Dean's Office in the management of Talbot House. Composed of two graduate and two undergraduate students, the committee will work with the Office in scheduling the facility, establishing policy, and keeping the books. This arrangement not only will offer an educational opportunity to the students participating, but also will make the administration of Talbot House more of a community effort.

The Student Center Committee is faced always with the problem of making the Student Center relevant programmatically and physically to changing student needs. The task involves an ongoing search for self-definition. The Committee has emphasized programs more this year than in the past, sponsoring a midnight movie series, an experimental 24-hour coffeehouse, the regular Potluck Coffeehouse, a second-term registration evening party, as well as supporting

in creative ways certain strike related activities in the spring. This has been done in addition to the administrative responsibilities assumed by the Committee. The current issue in the Student Center is governance: what is the optimum balance between student authority and student responsibility.

The 24-hour experimental coffeehouse which was in the Center Lounge of the Student Center during May represented something of an architectural and programmatic departure from the norm. It was furnished with Whitings milk crates, telephone cable spools, and overstuffed chairs. The food was homemade. There was spontaneous live music as well as recorded music available. This room was used constantly, providing an opportunity for relaxing and casual encounter as well as an atmospheric alternative to the other rooms in the Student Center.

There were two efforts made at a strike this spring. Both had trouble gaining momentum, as there seemed to be internal differences regarding the direction the movement should take. One notable event was an afternoon session in the Sala de Puerto Rico bringing together faculty and administrators with students to discuss the moral dilemma and possibilities for constructive action. An opportunity for direct conversation was helpful during this period of stress. The event was sponsored by the Student Center Committee.

Of exceptional merit this year were three sets of lecture/seminar presentations of highest quality which commanded attention and drew large audiences: the Technology and Culture Seminar Series, the Compton Lecture Seminar Programs, and the World Peace Seminar Series.

The M.I.T. Chapel and the programs associated with it continue to have their place in the life of the community. For the second year in succession there was a reduction in the number of weddings and in the number of religious services. Rabbi Herman Pollack, director of Hillel since 1952, retired in June. His contributions to the community throughout that 20-year period have been superb. We are grateful, and we wish him well.

JON HARTSHORNE

ROBERT J. HOLDEN

## Student Self-Governance and Participation in Institute Governance

The Dean's Office tried this year to help undergraduate governmental units improve their communications with each other, to support elected and appointed student leadership, and to expose to students the sheer breadth of student government. The latter task has been slow going, for approximately three-fourths of the 800 students involved in self-governance and participation in Institute governance operate in committees, boards, and task forces which do not have basic operating relationships with other units. This circumstance is perhaps most visible at the undergraduate level. This subject is being studied at the present time by the leadership of the Undergraduate Association, and its proposals for change are anticipated in the fall.

The major functioning agencies in which undergraduate student government interests intersect -- the Finance Board, Student Center Committee, Nominations Committee, and Association of Student Activities -- continued to refine their internal and mutual communications, and thus to increase their capabilities. A single example is the new division of function within the Finance Board, which assigns each member of the Board to become familiar and provide liaison with an assigned number of funded activities. It was through such measures -- far different from the explosive expansion five years ago in breadth -- that student decision-making

power continued to deepen its base. The Finance Board looks forward to a Conference of Activities Treasurers in the fall, while the executive committee of the Undergraduate Association is hoping to sponsor a leadership training program for individuals of all community organizations and activities.

The Undergraduate Assembly was essentially dead -- having met once or twice during the year -- and a student vote in the spring mandated the incoming Undergraduate Association President either to bury it or to bring it back in new form.

In contrast, the Graduate Student Council thrives, perhaps because it combines within its organization a variety of functions which in the Undergraduate Association are dispersed. Program components are both Council sponsored and decentralized to program units, whether those units are departmental, special interest, residential, or club.

Among the issues dealt with by the Graduate Student Council over the year were: 1) a proposal submitted to the Committee on Graduate School Policy that the archival theses requirement be changed so that the archival copy would be a microfiche, thus saving the student considerable money on typing costs; 2) establishment of an Ad Hoc Medical Advisory Committee as a means of bringing graduate student input to the Medical Department; and 3) the beginnings of a liaison with the Planning Office and various offices responsible for housing, to develop a more definite policy on graduate student housing. Approximately 40 graduate students served on 30 agencies of Institute governance and planning. The Council's President, William M. Mack, Jr., was a recipient of a Karl Taylor Compton Prize in recognition of his outstanding contributions to the M.I.T. community.

ROBERT J. HOLDEN

## Athletics

A major goal of our athletic program continues to focus on the improvement of program outlets for the M.I.T. community, with obvious priorities directed toward student interests. The past year has witnessed two advancements in support of this goal: first, administration endorsement of the Athletic Department's request for a "master plan" for the upgrading and expansion of facilities for athletics and recreation to meet program requirements through 1985; and second, significantly increased programming to meet the needs of the rapidly growing number of women within the community. As this report is being written, the Planning Office is involved deeply in the preparation of a planning report that will establish the specific requirements and priorities for athletic facilities. This work is scheduled for completion in the early fall. We look forward to the completion of this planning project, which will enable us to proceed with funding efforts.

Although this report carries a section on Intercollegiate Athletics for Women, the Department is following a general policy of attempting to meet the recreational needs of M.I.T. women within all areas of the existing program. In other words, we do not envision separate facilities or separate programs, i.e., intercollegiate competition. This and other policy decisions are being made in consultation with an advisory group of M.I.T. women representing students and staff.

To conclude these introductory remarks, the Department is keenly aware of the need to bring minority students into existing channels for student input in the planning and direction of our athletic program. We are particularly anxious to involve more black students in key roles in the Intramural Council and in student management of intercollegiate and club athletics. A review of the various athletic council memberships and team rosters will note real progress in the participant level. However, we need increased leadership in management, and particularly

in officiating in the intramural program.

## Program Highlights for the Year

*Physical Education*

There were a total of 4,905 registrations in 48 classes offered during 1971-72, including 1,335 registrations for no credit. These figures represent a 16 percent increase in total registrations and a 46 percent increase in registrations for noncredit classes over the previous year. Included are 308 registrations in 12 classes offered during the January Independent Activities Period, which represents a 22 percent increase over I.A.P. registration in January, 1971. Further analysis of this data reveals that ten M.I.T. and Wellesley College students registered for credit in physical education classes in the exchange program.

Five new classes were offered during the past year: folk dance, field hockey, women's gymnastics, figure skating, and ice hockey fundamentals. In looking ahead to next year, we have announced a new class in rock climbing, which will be taught by an M.I.T. senior, Wayne Christian, an experienced rock climber, using the Quincy quarries as a teaching station.

It should be noted also that the Committee on Curricula submitted a report which was accepted without question at the May 17, 1972, meeting of the faculty, announcing: 1) several innovations in alternative ways for students to fulfill the physical education requirement; and 2) that effective in September, 1972, that is, beginning with the Class of 1976, the physical education requirement will apply to all M.I.T. undergraduates, including women. This was made possible by converting dressing facilities, formerly reserved for visiting teams, to the daily use of women.

Registration Statistics for 1971-72

| | | | | | |
|---|---|---|---|---|---|
| Swimming | | 661 | Volleyball | | 168 |
| Beginning | 360 | | Pistol | | 162 |
| Intermediate | 33 | | Squash | | 159 |
| Red Cross Water Safety | 119 | | Golf | | 152 |
| Red Cross Senior Life Saving | 72 | | Beginning | 114 | |
| Scuba | 39 | | Intermediate | 38 | |
| Diving | 38 | | Rifle | | 149 |
| Tennis | | 526 | Modern Dance | | 142 |
| Beginning | 337 | | Karate | | 112 |
| Intermediate | 189 | | Sculling | | 85 |
| Development | | 448 | Badminton | | 76 |
| Sailing | | 315 | Gymnastics | | 131 |
| Skating | | 264 | Beginning | 49 | |
| Beginning | 206 | | Women's | 21 | |
| Hockey Fundamentals | 20 | | Trampoline | 61 | |
| Figure | 38 | | Skiing | | 69 |
| Folk Dance | | 206 | Part I | 41 | |
| Fencing | | 204 | Part II | 28 | |
| Archery | | 195 | Softball | | 63 |
| Judo | | 189 | Touch Football | | 61 |
| | | | Lacrosse | | 38 |
| | | | Field Hockey | | 22 |
| | | | | | 4,597 |

Noncredit Registrations

| Classification: | |
|---|---|
| Undergraduate | |
| Freshman | 153 |
| Sophomore | 188 |
| Junior | 200 |
| Senior | 229 |
| Graduate Student | 449 |
| Staff | 116 |
| | 1,335 |

*Intercollegiate Athletics, Men*

There has been a marked resurgence of interest among undergraduates in the keener disciplines characteristic of intercollegiate athletics. By actual survey of rosters for freshman, junior varsity, and varsity squads in 22 sports, approximately 815 male undergraduates participated in 427 regularly scheduled contests with colleges and universities in the New England and Eastern College Athletic Conferences. This statistic represent 22 percent of the 3,684 undergraduate men registered this past year.

Most notable among the varsity team achievements, judged by win-loss records, were: cross-country (11-2); water polo (11-6); wrestling (10-4); baseball (12-8-1 tie); and heavyweight crew, where M.I.T. defeated Columbia, Massachusetts, Princeton, Boston University, Wisconsin, Dartmouth, and Syracuse in regular season races, losing only to Harvard and Northeastern.

An interesting item of individual achievement is the fact that baseball pitcher Alan F. Dopfel, graduating this year in management and selected for the most valuable player award in the Greater Boston Collegiate Baseball League, was drafted by the California Angels this June. Of special significance also is the fact that 557 undergraduate men (varsity -- 272, junior varsity -- 132, freshmen -- 153) earned intercollegiate letter awards in 1971-72 in accordance with established criteria in each sport.

*Club Athletics, Men*

Club athletics embrace a variety of sports interests which are not met elsewhere in the program. The existence and extent of activity within a particular club are largely dependent on its current leadership. The Department encourages and supports club athletics within the practical limits of budget, in the belief that "clubs" bring together undergraduates, graduates, and faculty in informal athletics, thereby fostering highly desirable relationships outside the classroom. Club sports statistics for 1971-72 are:

| Club | Roster | Club | Roster |
|---|---|---|---|
| Badminton | 35 | Karate | 35 |
| Cricket* | -- | Rugby | 40 |
| Graduate Crew* | -- | Scuba | 30 |
| Graduate Soccer | 35 | Water Polo (Spring) | 15 |
| Ice Hockey | 40 | | |
| Judo | 40 | White Water | 25 |
| | | | 275 |

* Not active in 1971-72.

*Intercollegiate and Club Athletics, Women*

While only the sailing team has been accorded "varsity" status thus far, upon the recommendation of the undergraduate Athletic Association, there are additional competitive squads for M. I. T. women in field hockey, basketball, swimming, fencing, rowing, and tennis. With a continued increase in the number of women admitted to M. I. T., the Department is prepared to encourage and support those groups of women who demonstrate a commitment to competitive athletics.

Upon the recommendation of an Athletics Subcommittee of the M. I. T. Women's Forum, we have appointed a full-time woman to our staff to organize and coordinate the athletic interests of M. I. T. women. Similarly, we have made acceptable ad hoc arrangements for women's locker and dressing facilities, to bridge the gap between existing needs and the implementation of long-range improvements consistent with the "master plan" being developed in the Planning Office.

In summary, there is a hard core of approximately 70 undergraduate women who are committed to intercollegiate athletic interests. Although the number may seem small, it is not insignificant, since it represents approximately one-fifth of the 370 undergraduate women registered at the Institute in 1970-71. The number of women interested in team sports can be expected to increase in direct proportion to any increase in the number of women accepted for admission. Likewise, we anticipate an increase in the number of women's teams accorded "varsity" status.

This past spring, a nucleus of 15 undergraduates practiced regularly out of Pierce Boathouse at 7:00 a. m. and competed in four regattas. The men's freshman heavyweight crew coach doubled as the women's coach. On April 29, M. I. T. hosted a regatta of women's crews from Radcliffe, Princeton, Pennsylvania, and Williams College. On Sunday, May 14, an M. I. T. eight was one of 18 women's crews competing in an Eastern Championship hosted by Connecticut College for Women and subsidized by a rowing patron, Fred Emerson of Old Lyme, Connecticut. This is typical of the growth potential in the existing programs in basketball, tennis, fencing, field hockey, and swimming.

*Intramural Athletics*

Intramural athletics are planned and administered by the undergraduate Intramural Council, which is composed of the managers of each of the 20 sports sponsored by the Council, plus representatives of the Institute residences and the Interfraternity Conference. The teams are organized around the M. I. T. living groups and other campus oriented independent groups, which tends to motivate much of the enthusiasm which is characteristic of intramural competitions. Intramurals regularly constitute the largest segment of participation in the M. I. T. athletic program. An executive committee of the Intramural Council meets weekly with the Intramural Supervisor in planning, evaluating, and implementing the myriad details involved in a program of regularly scheduled events for 611 teams in 19 sports. (Golf was cancelled due to inclement weather this spring.)

During the weekends of the fall and spring outdoor seasons, the playing fields, except for the game oval, are committed to the scheduling of intramural events. During the long winter months, the ice rink and the indoor facilities are used for intramurals from early evening through midnight Sundays through Thursdays. Intramural cycling was added to the program this past year.

Intramural Participation Statistics for 1971-72

| Sport | Number of Teams | Number on Roster | Total Participants |
|---|---|---|---|
| Badminton | 23 | 5 | 115 |
| Basketball | 91 | 10.5 | 955 |
| Bowling | 52 | 3 | 156 |
| Cross-country | 6 | -- | 52 |
| Cycling | 4 | 4 | 16 |
| Football | 58 | 17 | 986 |
| Hockey | 44 | 12 | 528 |
| Rifle | 20 | 4 | 80 |
| Sailing | 5 | 4 | 20 |
| Soccer | 33 | 16 | 528 |
| Softball | 70 | 13 | 910 |
| Squash | 23 | 5 | 115 |
| Swimming | 10 | 12 | 120 |
| Table Tennis | 40 | 3 | 120 |
| Tennis | 32 | 4 | 128 |
| Track | 10 | -- | 120 |
| Volleyball | 53 | 9 | 477 |
| Water Polo | 20 | 12 | 240 |
| Wrestling | 17 | -- | 46 |
| | 611 | | 5,712 |

*Recreation for Students and the M.I.T. Community*

A major obstacle in meeting the recreational needs of the large segment of students who prefer casual or informal athletic activity, as opposed to a formally organized team or club program, is a shortage of facilities during the late afternoon hours. Most of the athletic plant is committed to the intercollegiate and intramural programs during the popular hours for recreation. A classic example is the Institute's complement of 16 squash courts, where only two courts at Walker Memorial are available to the "casual" between the hours of 4:00 and 7:00 p.m. Mondays through Fridays. Hopefully, the long-range "master plan" will provide more space for the casual, certainly for the student casual, during the popular hours. Fortunately, many casuals in the community have managed to adjust their schedules to exercise during the morning, midday, or other off-peak hours when the pressures on the athletic facilities are reduced somewhat.

The need for planning for casual recreation within the M.I.T. community is evinced by existing programs in jogging, women's conditioning, faculty/staff noon-hour volleyball, summer tennis instruction, swimming and ice-skating classes for faculty/staff children, Friday evening Family Swim Program, noon-hour softball leagues, etc.

The best numerical index of the amount of M.I.T. community interest in recreation is the record of sale of athletic cards entitling purchasers to privileges during open hours at the Institute's athletic facilities.

Athletic Card Sale for 1971-72

| | | |
|---|---|---|
| Student | | 5,693* |
| Faculty | | 387 |
| Staff/Employee | | 1,251 |
| Alumni | | 192 |
| | Total | 7,523 |
| Sailing Cards | | 1,571 |

* Approximately 77 percent of 7,304 undergraduate and graduate students registered in 1971-72.

*Cambridge Community Relations*

Through the auspices of the M.I.T. "Tutoring Plus" program, the Department extends to M.I.T. students the opportunity to bring those Cambridge youngsters with whom they are associated to the M.I.T. facilities during "open" hours. The usual guest fees are waived with the understanding that the M.I.T. students accompany their tutees throughout the visit, hopefully providing some instruction in the activity. Other uses of the athletic plant are extended to supervised Cambridge groups during term and summer recess periods, or during other hours when there is no conflict with commitments to our students.

*Major Athletic Awards for the Year*

| | |
|---|---|
| The Class of 1948 Award to the Senior Athlete of the Year | Alan F. Dopfel '72 |
| The Admiral Edward L. Cochrane Award to the senior who best combines qualities of leadership, humility, and scholarship in the intercollegiate athletic program | Kenneth R. Weisshaar '72 |
| The Eastern College Athletic Conference Merit Medal to the Scholar-Athlete of the Year | Paul E. Mitchell '72 |
| The M.I.T.A.A. Pewter Bowl for outstanding contributions to women's athletics by a woman student | Maria A. Bozzuto '73 |
| The Straight T Award, the highest award for athletic performance at M.I.T. | David J. Beck '72<br>Lawrence D. Bell '74<br>Harold Brown '72<br>Alan F. Dopfel '72<br>Robert B. Gibson '72<br>Walter E. Gibbons '73<br>Steven P. Nadler '73<br>Theodore B. Ruegsegger '72<br>Robert J. Tronnier '73<br>Karl A. Seeler '75<br>Thomas G. Williams '74 |
| The Burton R. Anderson, Jr., Award to the Manager of the Year | Jack E. Cater '72<br>Steven J. Goldstein '72 |

| | |
|---|---|
| The Varsity Club Award to the Freshman Athlete of the Year | David A. Deacon '75 |
| The Harold J. Pettegrove Award for outstanding contributions to intramural athletics | Kenneth R. Weisshaar '72 |

*Personnel*

R. Kirk Randall, Instructor in Physical Education and coach of freshman tennis and squash, resigned effective June 30, 1971. Manuel Weiss was appointed to replace Mr. Randall. Edwin A. Richards resigned as part-time coach of fencing. Eric T. Sollee was appointed to succeed Mr. Richards.

ROSS H. SMITH

# Vice President, Administration and Personnel

The Vice President for Administration and Personnel is accountable to the President for the operation and effectiveness of several of the Institute's central administrative offices. These are the Office of Personnel Relations, the Planning Office, the Office of Admissions, the Office of Student Financial Aid, and the Career Planning and Placement Office. The annual reports by the directors of these offices follow. They recount the flow of activity, significant trends, and staff changes. Embedded in these reports are several issues which must be dealt with, both by the staff members immediately concerned and by a number of others, for the degree of success in solving them will have Institute-wide impact. The Vice President for Administration and Personnel has singled out what he considers to be the four most important of these issues for particular comment.

The first of these is the number of well-qualified young men and women applying for an M.I.T. undergraduate education. Professor Roland B. Greeley reports that the decline in undergraduate applications from 1970 to 1971 was not repeated in 1972. This fact cannot be cause for complacency. For the rest of this decade, the number of young people reaching college age will be relatively constant. The costs of attending a private university are rising, and alternatives in the form of two-year community colleges, local state colleges, and major public universities of quality are increasing.

The challenge for this Office is to convey the nature, quality, and excitement of an M.I.T. education to the nation's high-school students and to their counselors and teachers. This is not solely a matter of the vigor of the Admissions Office staff or of the quality of its literature, but also of the way in which M.I.T. is seen and understood throughout the country. This Office must find better ways to convey the variety, the richness, the value of this learning experience, and the quality of M.I.T. as a place to live and learn in ways which dispel old stereotypes. This Office must particularly be more effective in reaching out to young women, for whom an M.I.T. education can be an extraordinarily rewarding experience.

The Office must, as well, intensify its search for minority students. It is increasingly conscious, as it presses ahead with the determined efforts to increase the numbers of minority faculty and staff members, that the enrollment of substantially larger numbers of minority students in quality undergraduate, and then graduate, programs is an essential precondition for significant progress at the faculty and staff level. In sum, one of this Office's principal challenges is to find better ways to reach those young people approaching college age for whom M.I.T. offers the best educational opportunity. The attention of the Admissions Office staff is focused on this issue; however, it will require, as well, the attention of many others throughout the Institute.

A related concern is that of financial aid policy and resources. The Institute's policy aims at aiding, through some combination of scholarship, loan, and job, all undergraduates whom it determines have needs beyond their and their parents' resources. The "equity" approach meets the first increment of "need" through a loan or loan/job combination with the additional amounts the student may require provided in the form of scholarship. The objective of this policy is to provide a uniform ceiling on the amount of debt students would incur as undergraduates from the costs of attending M.I.T. M.I.T. students have faced the same sharp rises in costs of their education -- in room, board, tuition and other expenses -- as

have other university students. Jack H. Frailey, Director of the Student Financial Aid Office, has pointed out that the average need of aid recipients in 1972 was $2,740; this compares with $2,390 the year before. There is no question that tuition fees must continue to rise in order to bear their historic share of the costs of education, unless, as cannot now be foreseen, there is some dramatic increase in the other major sources of support for higher education.

The financial aid problem is one of assisting the student to meet these increasing costs of education, and doing so with an approach which does not distort the socio-economic mix of undergraduate students at M.I.T. for economic reasons. One goal has been to maintain unchanged the proportion of scholarship aid in the total financial aid "package." The Institute has established financial aid as one of its top priority objectives among its fund-raising goals, with new gifts for scholarships receiving primary emphasis.

It is becoming evident, however, that students will be required to borrow in increasing amounts to finance their education. That they should do so is not an unreasonable expectation and, as Mr. Frailey points out in his report, M.I.T. "has been in the business of student loans for 40 years." A university education is an investment, and it is not unreasonable that the student should borrow to make that investment and should amortize it out of future earnings. During the course of the year, a new approach to student loans was devised, which includes repayment schedules related to M.I.T. graduates' probable income and the use of the Federal government's guaranteed loan program as an integral part of M.I.T.'s plan. The challenges for this Office are to convey to the prospective undergraduate who does not have the money to see him or her through four years of M.I.T. that the important measure of cost to them is not the total student budget, but the available family resources to help meet that budget. The Institute will help the student to obtain the balance through scholarship, loans, and term-time work. That is a problem of understanding on the part of prospective students and their parents with which this Office must cope. Second, the Institute, hopefully together with both Federal and state governments, must develop the sources of capital required to meet an expanding program of loans.

These have been issues in the Vice President for Administration and Personnel's area of responsibility as it relates to student admissions and financial aid. A third concern is that of finding ways to meet the expanding needs of the Institute for space to house its diverse activities. The staff responsibility for administration of space as a resource rests with the M.I.T. Planning Office, under the leadership of O. Robert Simha. That office has sought to understand and to deal constructively with the several dimensions of the space problem. It has developed INSITE II, a computer based system for inventorying and describing the Institute's existing space holdings. It has sought to develop measures of space utilization so that one might judge better the effectiveness with which space currently is being employed by its users. Finally, it attempts to keep abreast of new space requirements as they emerge.

It is clear that the Institute is undergoing substantial changes, as its educational and research programs move in new directions. A brief and very incomplete listing may serve to illustrate the point: the School of Architecture and Planning has pressed well beyond the limits of its historical physical boundaries, as it has moved to meet the challenges of an urban society; the Department of Ocean Engineering has become severely crowded as its faculty and student body have grown to meet new opportunities; the new Program in Health Sciences and Technology must be adequately housed; a renewed interest in the sources and applications of energy is requiring new space; and the Department of Physics is seeking more coherent space for its now scattered activities.

Some new resources are becoming available. As the Department of Electrical Engineering and the Research Laboratory for Electronics consolidate many of their activities in their new buildings, they will vacate space to meet other needs. Similarly, the construction of a

new home for the Department of Chemical Engineering will make its former space available for other uses. The key task is to match effectively and economically new needs to the present and expected inventory of space, and to convert to newer purposes older space whose utilization is less intensive as the activities housed therein have declined.

The fourth and perhaps most important issue to be faced relates to those who work at the Institute. This Office's goal is to make both the work and the environment of work at the Institute more rewarding. The dimensions of this task are formidable, but the problems will yield to persistent effort. The various classes of positions must be reviewed and, where possible, altered to enlarge the opportunity they offer for growth. This implies a consciousness on the part of supervision of the need for opportunities for self-development and for regular discussion with those who work for them about their goals and development needs. This Office must be more conscious of career paths and opportunities within the Institute, and it must provide more information to those who work here about new positions available, as well as encouragement to apply where they are interested and qualified. This Office has special obligations to review its policies and practices with respect to women and minorities employed at the Institute to ensure that they receive special encouragement and consideration for the development and application of their skills.

This Office must look, as well, at the more tangible rewards of employment at M.I.T. It must consider whether the pattern of benefits made available to the different groups are those which best meet their needs, and it must be sure that they are attuned to changes in the composition and attitude of those who work here and are properly meshed with those benefits which flow from national or local sources.

This is not a complete catalogue of concerns in the area of responsibility of the Vice President for Administration and Personnel, but the four areas noted are central to this Office's purposes and deserve priority attention. They will receive special emphasis over the next year.

This annual report would not be complete without mention of those who retired during the year and recognition of their contributions to the Institute. After 29 years as Alumni Placement Officer, Evelyn Yates has retired from that post. She was instrumental over those years in matching literally thousands of M.I.T. alumni with firms searching for men and women with particular talents, and she has earned the appreciation of alumni throughout the country and abroad.

Professor Roland B. Greeley, who served with great effectiveness for 11 years as Director of Admissions, elected to retire at the end of the summer of 1972. He brought wisdom, integrity, and dedication to his task as Director of Admissions, and he will be missed.

Alfred F. Sise retired this year from the position of Associate Director of the Office of Personnel Relations. A man of great vitality and zest for life, he contributed in many ways to the Institute over his 30 years of service.

JOHN M. WYNNE

## Office of Personnel Relations

The decline in nonacademic employment during the year brought no diminution of the activities of the Office of Personnel Relations, which found itself responsible for expanded and additional programs and services in a number of areas.

### Employment

Nonacademic employment on the campus, after having risen steadily since at least the late

1950s when formal records were first kept, experienced during fiscal year 1972 a decrease of 4.1 percent. Pressures on budgets caused a curtailment of hiring in all categories of personnel, and layoffs which had begun in 1970 continued into the fall of 1971. Meanwhile, employment in both the Lincoln Laboratory and the Draper Laboratory Division of the Institute, which had declined for several years, reversed direction and increased during FY 1972. The year-end levels were:

| | June 30, 1971 | June 30, 1972 |
|---|---|---|
| Campus | 4,109 | 3,942 |
| Draper Laboratory | 1,571 | 1,594 |
| Lincoln Laboratory | 1,624 | 1,784 |
| All M.I.T. | 7,304 | 7,320 |

Because of the greatly reduced number of job openings in all categories, the Institute's progress toward its goals for the employment of members of minority groups was numerically smaller than in the previous two fiscal years. In percentage terms, 18.5 percent of persons hired on campus in the office and hourly categories were minority group members, compared with 14.3 percent two years ago. This modest progress leaves much room for improvement. Moreover, although termination rates declined during the year, there was a slight increase (to 11.1 percent) in the percentage of minority group members among those terminating. To promote better retention, the Office of Personnel Relations has readied further training programs to help new employees acquire or improve needed skills. Additionally, in its daily contact throughout the campus, the Office is seeking to encourage affirmative action in the selection of candidates and in the enlargement and development of jobs to make career growth possible.

To increase the percentage of minority applicants despite the reduced number of job openings, this Office cultivated working relationships with many agencies in the black community, as well as in the Spanish-speaking and Chinese communities. The Office responded also to requests from community groups to assist in the placement of disabled and handicapped persons, ex-convicts, and ex-drug addicts, and joined in an employer advisory group to improve working relationships with the local Division of Employment Security Office.

Competing with new applicants, of course, were other persons to whom special attention and efforts are always due: employees about to be laid off or already on the recall list, and present employees seeking transfers. The layoffs begun during the preceding fiscal year continued well into the year just ended, and a few were still occurring on campus in June. Personnel representatives, occupied with the sensitive and sometimes complicated procedures of layoff and "bumping" and a number of union grievances which arose in the process, devoted many hours to finding jobs elsewhere at M.I.T. or on the outside for the individuals affected.

In furtherance of the Institute's equal opportunity commitments, the Office listed openings in Tech Talk and systematically and persuasively promoted internal advancement and transfer, not only for minority and female employees but for all present employees. These efforts contributed to growing cooperation in the policy of promotion from within, as shown by the number of employees advanced during the year from non-exempt to exempt positions and from exempt to professional staff, notably in the administrative areas. The number of transfers within the office category also increased, with job growth a principal objective.

The Institute's equal opportunity efforts have entailed not only a permanently increased workload of record-keeping and statistical reporting for virtually every member of this Office, but also additional programs, new procedures, and special studies and reports on various aspects of the Institute's compliance with laws and regulations and its progress toward affirmative

action goals. In particular, the exit interview program has proved time-consuming, especially in the biweekly area, where turnover on the campus runs over 500 a year. The special summer job program for disadvantaged and minority students, as another example, has been strengthened each year and most recently was expanded to include weekly workshops on topics such as ethnic identity, drug abuse, and job stability.

## Training and Education

The Federally assisted office skills training program begun in the previous year was successfully concluded. Of 22 newly hired employees, 18 completed the program of combined classroom instruction and on-the-job training and took on their full-time roles. A pilot program for upgrading office skills of present employees was launched. A systematic survey of the further training needs of the Institute was begun in the spring as a basis for planning future programs.

Tuition assistance with career related study continued to be utilized by both professional staff and other employees. In the winter, the maximum annual tuition reimbursement for after-hours study was raised from $400 to an effective maximum of $625 (100 percent up to $500, plus half of any excess between $500 and $750). Also, nonprofessional employees were for the first time offered the opportunity, formerly limited to professional staff, of being reimbursed at 75 percent for subjects taken at M.I.T.

## Compensation and Benefits

Annual reviews of salaries and wages were carried on within the limits of formulas necessitated by President Nixon's wage and price stabilization guidelines. Probationary adjustments, however, had to be eliminated.

Several important changes and improvements were made in the benefits program for faculty and staff. These included a 20 percent increase in the amount of group life insurance coverage, a number of major improvements in the retirement plan for staff members, the extension of eligibility for the Children's Scholarship Program to Division of Sponsored Research (D.S.R.) staff members, and an increase from $15,000 to $50,000 in the lifetime maximum for extended benefits under the M.I.T. Blue Cross and Blue Shield plan. However, because of the drastically increasing costs of providing health care, it became necessary to increase the staff member's share of the cost of our plan.

The Benefits section of the Office enlarged upon its individual counseling of employees about to retire by introducing a series of seminars on preparation for retirement. The response to these seminars indicated that they fill a need and should be continued.

The Office of Personnel Relations continued a program begun one year earlier to give increased recognition to its retiring employees, including a now annual retirement dinner and presentation of "diplomas" to 119 retirees this year. The activities of the Quarter Century Club and the Silver Club were also assisted by this Office.

On January 1, all Institute employees became covered under the unemployment compensation provisions of the Massachusetts Employment Security Law. This Office took on responsibility for developing and administering the necessary policies and procedures to comply with the law.

The Office of Personnel Relations continued to assist in the administration of a Child Day Care program for children of employees. It again provided the administrative backing for the M.I.T. Red Cross Blood Drive and for the annual campaign on behalf of the United Fund and United Black Appeal. In these two programs of community participation the Institute bettered its previous performances, continuing its record of achieving the highest level of blood donations and the second highest level of United Fund giving of all universities in the area.

### Union Relations

This office conducted the Institute's relations with four unions representing six bargaining units (the Faculty Club unit having been added during the year to the previous five). In addition, it held discussions with committees representing the Campus Police and the D.S.R. Security Guards. As all union agreements terminated on June 30, negotiations toward new agreements were under way at the close of the year.

ROBERT J. DAVIS

## Planning Office

### Long-Range Planning

The Planning Office's long-range activities have concentrated on the broad aspects of the Institute's physical environment. An intensive, thirteen-month investigation of the development potential of the Simplex property, the Northwest Area Pilot Plan, was brought to completion this year. As part of a review of the future development of the Charles S. Draper Laboratory, the Planning Office completed a detailed assessment of the Laboratory's physical facilities.

The West Campus Study, integrating the development options for circulation, parking, athletic facilities, housing, and community facilities, has continued to receive attention and will be completed in the fall.

The Planning Office has continued its involvement with the Cambridge community by sharing both information and expertise on such projects as the Kendall Square Urban Development, the Cambridge Riverside Zoning Study, and the Boston Transportation Planning Review.

In an effort to raise the quality of information in the area of college housing, campus planning, and environmental development, the Planning Office sponsored a conference for the Society for College and University Planning on "fast track" housing.

### Research and Analysis

During the past year, a major research effort in the ongoing M.I.T. Planning Office housing program was completed. This was the tabulation, analysis, and publication of results of the two 1970 housing surveys, one for faculty and staff and one for graduate students. Each survey includes a technical report and an analysis section. The technical reports are compendia of statistics organized around important sectors of the housing market and important market variables. Each analysis briefly describes the salient patterns which emerge from the tables of statistics. The housing surveys stand alone as research products and were also used as an input to the Northwest Area Pilot Plan effort.

Additionally, the second annual computer census of M.I.T. students tabulated by residence type and location was generated this past year. This census is based on a file maintained by the Registrar and timed to coincide with the fall term "fifth-week count." Analysis of the census enables student residence location patterns to be monitored easily and in terms of a standard set of geographic definitions.

### Building Programming/Design Review

Building programs and proposals prepared this year included a final building program for the Department of Chemical Engineering, a proposal for a Cancer Research Facility, a program for the restoration of Ashdown House, and a program for the Department of Physics.

The design review of projects underway was accomplished in periodically scheduled meetings which included the architects and the members of the client team for each project. These projects included: 1) the Electrical Engineering and Communications Research Facility, now in the construction phase and scheduled for completion in the spring of 1973; 2) the new facility for the Department of Chemical Engineering; 3) major renovations to Burton-Conner, which were completed in September, 1971; 4) design review for the J. B. Carr Indoor Tennis Center, completed and occupied in October, 1971; 5) the Westgate II project for graduate student housing, now under construction and scheduled for completion in the fall of 1972; 6) site development and landscape for Westgate I and II, which will be undertaken in early July and will be completed by October, 1972; 7) renovation of classrooms in Building 4, which was completed in January, 1972; 8) renovation of faculty offices, graduate student offices, department headquarters, and undergraduate headquarters for the Department of Mathematics in Buildings 2 and 4, which were completed in the spring of 1972; 9) renovation of laboratories and offices in Building 6 for the Department of Chemistry, which were occupied in the spring of 1972; 10) a continuing program for renovation of the main group's corridors, including the painting of walls and stairwells and the installation of a series of exhibitions; and 11) landscape improvement projects including the introduction of planter tubs in building lobbies and the completion of landscape north and south of Burton-Conner, at Amherst Alley of W-5, and planter tubs at Massachusetts Avenue and Vassar Street.

## Space Administration

Planning and administrative services for over 60 space change projects were provided during the year. Such services varied with each project, but generally included planning, preliminary cost estimating, scheduling considerations, negotiations with competing activities, surveys, and studies. Approximately 288 rooms were reassigned with the authority, approval, or direction of the Committee for Space Planning. Such assignments were, in some cases, routine, while others involved extensive negotiations, coordination, and study to ensure validity, viability, or general acceptance of each assignment. The unusually dynamic nature of Institute operations and mobility of campus activities demand constant shifting, expansion, consolidation, and reorganizing of campus spaces.

## Community Planning

Community planning activities this year were focused on four areas of concern to the Institute: 1) child care; 2) women's programs; 3) social services for the elderly; and 4) liaison with local community groups and governmental agencies.

The staff has performed a developing, coordinating, and consulting function in child care services. Last summer a family day care program was established. Original materials and manuals were developed for the program, and training workshops were organized and carried out for student parents participating in the program.

Monitoring and evaluation of M.I.T.'s participation in the KLH Child Development Center continued throughout the year.

To promote further an exchange of ideas and understanding of child care programs in Cambridge, the staff represented the Institute on the boards of several organizations concerned with child care.

In addition, the staff assisted several governmental agencies, including the Office of the Governor, with the preparation of new child care legislation. All of these activities have led to the preparation of a comprehensive report on child care for the Institute community.

In connection with M.I.T.'s efforts on behalf of the elderly in Cambridge, the staff: 1) developed the format and coordinated a conference for 350 Cambridge senior citizens to meet with 60 state and local officials and private suppliers of services; and 2) developed program

alternatives for the delivery of social services in public housing for the elderly, as an adjunct to M.I.T.'s construction of 684 units of turnkey housing.

Furthermore, the staff: 1) developed a proposal for a program of community participation in the planning and development of a twenty-acre site owned by the Institute adjacent to the campus; and 2) monitored the programs of public and private agencies working on projects of concern to the Institute in areas such as transportation planning, housing, and local tax policies.

Currently, major staff energy is being focused on equal employment opportunity programs with special concern for the Institute's affirmative action plan for women.

### Planning Systems

Two of the most rewarding experiences this year were the decisions by Harvard Medical School and Brown University to ask for help in transferring to them both M.I.T.'s space inventory system and the knowledge required to put it to use for the benefit of their own institutions. This transfer of technology is not only in keeping with one of the Institute's long-standing policies, but it provides yet another link in a chain of joint efforts among sister universities.

Also completed this year was a pilot study of the School of Engineering's physical facilities to devise meaningful measures for the relative comparison of space needs among the School's departments. The success of this effort will soon lead to the inclusion of data for all of M.I.T.'s academic space users.

Space inventory information was not only provided on a continuing basis throughout the year to numerous M.I.T. administrators requiring such data, but was also used for the fulfillment of M.I.T.'s annual space inventory reports required by the Department of Health, Education, and Welfare and the Massachusetts Board of Higher Education.

The annual updating of the Planning Office report, Building Data: Academic Facilities was accomplished along with the creation of two new reports, Building Data: Investment Properties and Land Data: Investment Properties. Although available funds limited this inventory of investment properties to the Cambridge area, it does provide M.I.T. with a single source of such information for the first time.

Other space data and system support was provided for such efforts as the Program for the Department of Chemical Engineering Facilities, an Athletic Facilities Study, the Draper Laboratory Planning Project, and M.I.T.'s Capital Budget System — MITCAP.

O. ROBERT SIMHA

## Office of Admissions

During the rest of the decade of the 1970's the number of young people reaching college age each year will be relatively constant. Changes in the total number of freshmen will thus be a direct function of change in the percentage of high-school graduates going on to college. If the numbers going to two-year colleges and to local state colleges increase faster than the total numbers going to college -- and the two have run almost parallel for the past four years -- then the number going to private colleges and major universities will necessarily decline. In any event, the competition for the extremely well-qualified high-school graduate -- the kind M.I.T. seeks -- must inevitably become stiffer over the next several years. Unquestionably the less well-known private colleges will suffer seriously. Quite possibly the major prestige colleges will hold their own; for them, collectively, to gain in numbers and quality will be very difficult.

M.I.T., like most of the rest, has witnessed decreases in numbers of completed applications and in yield, from the peaks of 1969 and 1970. Fortunately, the sharp decline in 1971 was not repeated in 1972 -- most figures for the two years are almost identical, despite the fact that the decline continued for most "engineering" schools. Last year's experience made the Office cautious, perhaps overly cautious, to the extent that M.I.T. slightly overadmitted and probably will register the largest class in its history -- a few more than last year's record.

Despite vigorous efforts to emphasize to secondary schools and potential applicants the realities of coeducation at M.I.T., the Institute was unable to attract as many qualified women applicants this year as last. Insofar as could be managed, there was no bias one way or the other in the selection process, but the results will be a slight decrease in the number of freshman women. Possibly one explanation for the failure to recruit more women is the increasing size of the female contingent in most of the Institute's major counterpart colleges, including both the Ivies and the major technological institutions.

Similarly, competition for minority group students has become so severe that M.I.T. and many others are experiencing increasing difficulty in attracting as many blacks and Spanish-Americans as they did a year or two ago. Efforts have been pursued more assiduously this year than in any previous year, but without an increase in the number of applicants. Special attempts to find native Americans (American Indians) who could realistically be encouraged to apply did not turn up a single qualified applicant. Project Interphase is being operated as usual this summer but with fewer students than in any summer since 1968.

This has been the first year in which foreign applicants, both undergraduate and graduate, have had to pay the normal $15 application fee. This has markedly reduced the number of applications, both for undergraduate and for graduate status; but, insofar as can be measured, the result has been highly successful in cutting down on total numbers without discouraging application by those who are really serious and well-qualified. The fee is waived on request where to charge would impose severe hardship.

## Recruiting

Over the past decade there has been a gradual, but inexorable, increase in the amount of effort devoted to seeking applicants. Major changes have been in the direction of concerted efforts to attract more blacks, Spanish-Americans, native Americans, and women. Suggestions have been made, but not consciously adopted as yet, to focus similar special efforts on recruiting students aspiring to become engineers. Throughout this period of transition the basic principle of the Admissions Office, supported by the Faculty Committee on Undergraduate Admissions and Financial Aid, has been to affect the composition of the freshman class by influencing the applicant group rather than by manipulating the selection process: if M.I.T. wants more blacks, more women, etc., it must be done by getting more qualified applicants, not by altering the quality standards for specific groups. The Office has deviated slightly from this principle to the extent of being very liberal or "flexible" in interpreting C.E.E.B. test scores submitted by members of minority groups. As far as can be detected, no one knows how much of a differential it is appropriate to apply in such interpretation; certainly some is essential in the interests of fairness and equality of performance results. Possibly the Office was more liberal than subsequent facts will justify, to the extent that academic attrition at M.I.T. for some of those admitted under the flexible program exceeded expectations. As a consequence, flexibility formulae were modified this year, in the hope of reducing the amount of attrition in the Class of 1976.

In addition to the specific types of recruiting mentioned above, it seems abundantly clear that the total application picture will be sufficiently uncertain, if not unstable, over the next few years to demand generally more aggressive tactics in encouraging applications. To this end, publications of general as well as specialized nature are being revised to be more

compelling and less simply expository. In addition, the Office is reorganizing its approach to work in the field, with both secondary schools and members of the Educational Council, in an effort to augment the effectiveness of field programs in the face of increased need and decreased budget. Even if the newly instituted regionalized approach meets expectations for increased effectiveness, it seems likely that the current cuts in funding of field work will have to be restored for FY 1974 or else recruitment will suffer seriously.

## Selection Process

The Office repeated this year the faculty-admissions officer team basis for selecting a sizeable number of the freshman applicants. Nine teams, comprising two faculty volunteers plus an admissions officer, each took full responsibility for reviewing and acting upon 150 applications selected at random. This lightens somewhat the load on admissions staff, gives the faculty volunteers a real insight into the caliber of the applicant group and the nature of the selection process, and produces results quite consonant with those resulting from the traditional group decision process -- in which the reviewers of the applicant folders are not necessarily the same individuals who make the final decisions. Both processes are followed by a staff check for internal consistency, in the hope of avoiding any examples of real unfairness to an applicant.

## Graduates, Transfers, Specials

By far the biggest change in the graduate application picture was the reduction in the number of applications from foreign students, especially those studying abroad. This was anticipated as a consequence of the decision to collect application fees ($15), except in what seemed to be truly distress situations. The Office estimates that about 500 fewer applications than "normal" were received, but that very few who were lost would have been acceptable candidates. Thus, the graduate application figures look low this year, but in fact the situation was at least as favorable as last year. Numbers accepted and expected to register are slightly up, but not significantly over a year ago. There are no marked changes in course distribution; each School has had very nearly the same number of applicants from U.S. citizens as last year. The School of Engineering experienced a 5 percent increase, as contrasted to the School of Science's 7 percent decline. Of the departments with large numbers of applications (more than 100), the Department of Architecture was the only one with an increase of more than 25 percent; the Department of Mathematics experienced the greatest decline, 21 percent.

The transfer situation remains stable at just over 100 transfers registered. Indications over the past few years that transfer activity will increase significantly have been borne out; but at the same time many of M.I.T.'s counterpart colleges have gone from positions of strong reluctance to positions of relative readiness to accept transfers. The Office anticipates that the numbers of students moving from college to college, as transfers or specials, will continue to increase, yet it seems unlikely that numbers of matriculated transfers will rise appreciably until M.I.T. takes either or both of two steps: 1) the Institute makes it clear that it actively seeks transfers, if they share its interests and levels of qualification; or 2) the Institute evolves some means of facilitating transfer of students from two-year colleges who, typically, will not have attained the math-science levels normally expected in the first two years of study at M.I.T.

There has been a significant decline in the number of special students, especially at the graduate level; there were only 312 this spring compared to 429 three years ago. This trend seems to reflect directly economic conditions of industry and government research in the local area and is likely to continue to fluctuate with those conditions.

## Ivy League Cooperation

During the year many apparent inconsistencies evolved among members of the Ivy League (with which M.I.T. is a formal cooperator), regarding the timing and informal notification of applicants. In view of this, a special study of desirable notification practices was initiated.

The report of the consultant staff will be reviewed in some detail during the summer of 1972, and it is likely that widespread changes will be recommended, aimed at effecting use of common notification procedures and a common calendar more attuned to present conditions. The Office urgently hopes that M.I.T. will help to formulate, and ultimately to concur in, a final set of procedures which will prove acceptable to the members of the Ivy League and, hopefully, to many other colleges in the Northeast.

## Operations

During the year this Office conducted two experiments of note in the area of minority recruiting. In January the Admissions Office brought, at M.I.T.'s expense, four bus-loads of minority students from relatively underprivileged schools in the New York-New Jersey area, Philadelphia, Washington, and Buffalo. Approximately 150 high-school juniors and seniors enjoyed two-night stays on campus as guests of the Black Student Union, visited a great variety of events both normal and special, and met many of the faculty and administrative staff. Most of them enjoyed the experience, as feedback to their schools proved highly favorable. Only two or three additional students came to M.I.T. this yearwhose matriculation can be credited to that experience; however, the Office is hoping to identify more significant effects of the experience in next year's applicant group.

The other experiment involved bringing seven Pueblo Indians, high-school juniors or seniors, from the Southwest for a similar opportunity to see M.I.T. firsthand. It was an enormously eye-opening trip for them. Unfortunately, it is unlikely that any of these students will be qualified to enter M.I.T. because, due to basic misunderstanding, none of those selected will have had enough math and science to qualify. In common with most of their fellow native Americans in predominantly segregated schools, their curricula do not include much of the basic work which is required for M.I.T.'s freshman core program.

M. William Dix, Class of 1967, executive secretary of the Educational Council for two and one half years, resigned in June to continue his education at the Sloan School. His quiet, effective performance, his unusually thoughtful judgments, and his warm and friendly manner will be missed deeply.

This will be Professor Greeley's last report to the President, as he retires soon, after 11 years as Director of Admissions. It has been a thoroughly enjoyable, challenging, rewarding experience, thanks primarily to the untiring efforts of superb professional and support staffs, the cooperation of nearly 1,000 devoted alumni members of the Educational Council, and the continuing interest and guidance of the Committee on Undergraduate Admissions and Student Aid, the Office of Student Financial Aid, and numerous members of the faculty and administration.

ROLAND B. GREELEY

ADMISSIONS OFFICE STATISTICS 1971-72

| | 1970 | 1971 | 1972 |
|---|---|---|---|
| Entrants from secondary schools: | | | |
| Preliminary applications | 7,648 | 6,468 | 5,960 |
| Final applications | 4,896 | 3,842 | 3,665 |
| Admissions offered | 1,600 | 1,758 | 1,840 |
| Actual registrations | 942 | 983 | 1,040 |
| Registrations as percent of admissions | 59% | 56% | 57% |
| Number of secondary schools represented | 737 | 804 | 837 |
| Percent of students from Northeast states | 45% | 50% | 50% |

| | 1970 | 1971 | 1972 |
|---|---|---|---|
| College transfers: | | | |
| Total applications | 773 | 829 | 736 |
| Applications completed | 381 | 348 | 334 |
| Admissions offered | 143 | 150 | 177 |
| Actual registrations | 120 | 100 | 121 |
| Registrations as percent of admissions | 84% | 67% | 58% |
| Graduate Students: | | | |
| Total applications | 6,556 | 6,485 | 6,117 |
| Admissions offered | 1,952 | 2,111 | 2,241 |
| Actual registrations | 1,015 | 1,191 | 1,247 |
| Registrations as percent of admissions | 52% | 56% | 56% |
| Number of personal interviews: | | | |
| At M.I.T. | 1,949 | 1,791 | 1,826 |
| By Educational Counselors in New York City | 245 | 183 | 203 |
| Other Regions | 2,991 | 2,523 | 2,407 |
| Total | 5,185 | 4,497 | 4,436 |
| Number of persons taking tours of M.I.T. | 4,057 | 3,630 | 3,309 |
| Number of secondary schools visited: | | | |
| By Educational Counselors (College nights) | 125 | 111 | 111 |
| By Faculty and Administrative Staff members | 59 | 57 | 45 |
| By Admissions Office staff | 219 | 413 | 459 |
| By students | 109 | 28 | 14 |
| Total | 512 | 609 | 629 |

Advanced Placement

| | Number of students seeking credit | | Number of students receiving credit | | Number of subjects credited | |
|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1970 | 1971 | 1970 | 1971 |
| Procedure: | | | | | | |
| College Board test program | 437 | 468 | 278 | 305 | 450 | 564 |
| Advanced Standing Exams | 12 | 34 | 12 | 20 | 14 | 16 |
| College transcript | 46 | 71 | 45 | 50 | 96 | 101 |
| "A" Level Exams | 16 | 13 | 16 | 13 | 35 | 46 |
| Total | 486* | 542* | 326* | 350* | 595 | 727 |

| Subjects credited | Number of terms credited | | |
|---|---|---|---|
| | 1969 | 1970 | 1971 |
| Chemistry | 107 | 112 | 140 |
| Physics | 71 | 78 | 116 |
| Mathematics | 379 | 254 | 304 |
| Other specified subjects | 15 | 22 | 31 |
| Elective credits (6 units each) | 132 | 108 | 147 |

* Includes several seeking credit by more than one means

# Office of the Advisor to Foreign Students

A general summary of statistical information on the operations of this Office is set forth below. The enrollment figures for the number of citizens of other countries is based upon the official Report of the Registrar on all classifications of students as of October, 1971. The 1972 trends in the admission of foreign students are still undetermined as offers of admission, particularly to graduate-level and to upperclass college transfer candidates, are not completed as of this writing. The activities of the various members of the Office of the Advisor to Foreign Students staff, the operations of the M.I.T. Host Family Program, as well as the various foreign student organizations related to this Office conclude this report.

The foreign student population at M.I.T. during the 1971-72 academic year rose from a figure of 1,328 for the preceding academic year to 1,396. Based on the 1971 fall term student population of 7,717, these foreign students represented 18.2 percent of the total student enrollment. This is the highest percentage figure for this category of students since the Office was established in 1944. A section of the 1971-72 Foreign Student Profile, noting enrollment in the five major Schools is appended to this report.

There are 410 foreign students registered as undergraduates and 899 as candidates for advanced graduate-level degrees. The departments of the School of Engineering enrolled 713 foreign students during the 1971-72 academic year. This accounts for some 51 percent of the total foreign student enrollment. This is followed by the School of Science with 289, the Sloan School of Management with 129, the School of Architecture and Planning with 84, the School of Humanities and Social Science with 83, and 98 undesignated undergraduates. It is no surprise that the majority are male (1,319). The women students number 77 -- a slight increase over the previous year.

Student representation by country of citizenship places Canada first with 159. This is followed by 17 nations or political entities with delegations of 20 or more students: Hong Kong -- 112; Republic of China -- 104; India -- 99; Japan -- 77; United Kingdom -- 68; France -- 56; Greece -- 47; Korea -- 37; Israel -- 35; Brazil -- 32; Colombia -- 27; Turkey -- 25; Iran -- 24; Pakistan -- 24; Venezuela -- 24; Thailand -- 21; and the Federal Republic of Germany -- 21. Among the nations of Africa, the countries with delegations of five or more are: Ghana -- 12; Egypt -- 9; Nigeria -- 7; Republic of South Africa -- 7; and Kenya -- 6.

## Admission Trends

A year ago, for the term beginning in September, 1971, it was noted that 460 foreign students had been offered admission. Thus far this year 467 foreign students have been offered admission for the term beginning in September, 1972. The majority (some 400) are graduate students. Undergraduates (freshmen and college transfers) will number about 90. There are, at the graduate level, 23 nations with delegations of five or more new students. Countries with significant numbers of admitted graduate students this year are: India -- 33; Canada -- 32; United Kingdom -- 29; France -- 28; Japan -- 26; Hong Kong -- 25; Taiwan -- 21; Brazil -- 18; Korea -- 11; Mexico -- 11; and Colombia -- 10.

It is worth noting, however, that a significant number of foreign students who were offered admission to the various graduate departments -- perhaps more than half that number -- have been judged to have insufficient dollar funds to meet the tuition, medical fees, and maintenance costs of attending M.I.T. Many of these will find means through assistantships, government grants, and other sources to cover their first-year costs. However, it may be that because of a lack in general funding for foreign students, a larger number of graduate students than usual will simply not find the dollar resources to satisfy the Advisor to Foreign Students that it is reasonable to admit them fully to the Institute.

It is anticipated that 65 foreign students will enroll as freshmen for the 1972 fall term. There were just over 240 formal applicants this year in contrast to the 370 who applied for the 1971 term. The reason for this decline in formal applications is not only due to the high cost of tuition but is also attributable in part to the imposition of the application fee. Twenty-six nations will be represented among the freshmen enrolling in the 1972 fall term.

Of the more than 220 foreign students who initiated applications as undergraduate college transfers for September, 1971, offers of admission were made to 41. Twenty-four -- many of whom were recipients of financial aid -- accepted this offer and enrolled. This yield is considerably smaller than in the past. It is too early to predict with any precision what the applicant group will look like for September, 1972, but it appears as if there will be fewer applications, especially from students applying from universities abroad. The academic quality of the college transfer group remains very high and it is expected that the number determined to be admissible will be about the same as last year. In general the level of academic performances of the foreign transfer student is excellent.

## Office Activities

Members of this staff, in cooperation with the staff of the Dean of the Graduate School, undertook to review the policies of the several graduate departments in admitting and awarding financial aid to foreign students. This report is to be published this summer. A similar inquiry covering 12 universities but limited to six graduate disciplines was funded by a grant from the Field Service Program of the National Association for Foreign Student Affairs. A task force chaired by Dr. Robert A. Schuiteman published the results of this inquiry in April, 1972. It is also being made available to appropriate offices throughout the Institute.

The International Student Association of Greater Boston, at 33 Garden Street in Cambridge, will close out its activities of providing hospitality and community related programs for foreign students during the summer of 1972. M.I.T., through Mrs. Karl T. Compton and Professor Paul M. Chalmers, has been closely allied with this organization. It also has drawn on M.I.T. student leadership for many of its activities. In its time it provided links through its hard working staff with various communities in New England and met the various needs of the foreign student community for a central meeting place not then provided by the universities in the area. Changes in the total foreign student community, funding of ongoing services and a decrease in the number of volunteers from the community have brought about its closing.

I.S.A. has turned over the operations of two of its former contract activities -- the Arrival and Visit Programs -- to the newly reorganized Boston Area Seminar for International Students, Incorporated. BASIS will administratively serve the interests of the International Student Service organization of New York in providing assistance to foreign students arriving at Logan Airport. BASIS, now incorporated as a non-profit educational organization by the State of Massachusetts, is governed by an Executive Committee and Advisory Board drawn from Foreign Student Advisors in Boston and from other New England institutions. The Advisor, Eugene R. Chamberlain, currently serves as President of BASIS.

## The M.I.T. Host Family Program

Now in its eleventh year, the Host Family Program under the direction of Mrs. Robert E. Stickney, continues to offer to foreign students new to this community the opportunity to meet families in metropolitan Boston. Nearly 200 new students were assigned to Host Families last year. The families participating in the program are often M.I.T. alumni or staff-related, however, some are simply friends of the Program.

## Foreign Student Activities

Organized more than a decade ago with the support of the Advisor and interested leadership

of undergraduate foreign students, the International Students Council last year opened an International Student Lounge on the second floor of Walker Memorial. It is to serve as the focal point for the some 27 nationality clubs which flourish at M.I.T. In March, 1972, this Lounge was formally dedicated as the Paul M. Chalmers Lounge for International Students. Professor Chalmers served as Advisor to Foreign Students at M.I.T. from 1944 to his retirement in 1966. The Lounge, tastefully furnished, has an extensive library of Chinese periodicals and journals from other nations and is equipped with a short range radio to pick up broadcasts from around the globe. The Council's activities for the year were under the leadership of Mr. Dominic Ho, Class of 1973.

## Personnel

Mr. Tekle A. Tomlinson, Assistant Director of Admissions and Assistant Advisor to Foreign Students, participated as a resource leader in the regional conference of the National Association for Foreign Student Affairs. Dr. Robert A. Schuiteman is a member of the Foreign Student Financial Aid division of the College Scholarship Service organization.

EUGENE R. CHAMBERLAIN

ACADEMIC LEVEL OF FOREIGN STUDENTS AT M.I.T.
BY SCHOOL AND DEPARTMENT

| Schools and Departments | YEAR 1 | 2 | 3 | 4 | G | Specials | Total |
|---|---|---|---|---|---|---|---|
| Undesignated | 80 | 13 | 1 | 0 | 0 | U 4 | 98 |
| Architecture and Planning | 0 | 3 | 7 | 7 | 50 | G 17 | 84 |
| Architecture | 0 | 2 | 7 | 4 | 29 | G 3 | 45 |
| Urban Planning | 0 | 1 | 0 | 3 | 21 | G 14 | 39 |
| Engineering | 0 | 50 | 54 | 77 | 489 | U(3) 40 | 713 |
| Civil | 0 | 4 | 4 | 4 | 68 | G 15 | 95 |
| Electrical | 0 | 30 | 30 | 44 | 102 | G 5 | 211 |
| Mechanical (incl. IIT) | 0 | 4 | 10 | 8 | 79 | U(2) 2 | 105 |
| Chemical | 0 | 9 | 4 | 8 | 54 | G 2 | 77 |
| Aeronautical | 0 | 1 | 3 | 7 | 53 | G 1 | 65 |
| Metallurgy | 0 | 1 | 0 | 5 | 50 | G 1 | 57 |
| Nuclear | 0 | 0 | 0 | 0 | 45 | G 0 | 45 |
| Ocean | 0 | 1 | 3 | 1 | 38 | U(1) 2 | 46 |
| Engineering Studies | 0 | 0 | 0 | 0 | 0 | G 12 | 12 |
| Humanities and Social Science | 0 | 1 | 7 | 6 | 63 | G 6 | 83 |
| Economics | 0 | 1 | 4 | 3 | 36 | G 2 | 46 |
| Political Science | 0 | 0 | 0 | 1 | 9 | G 2 | 12 |
| Humanities | 0 | 0 | 1 | 1 | 0 | G 0 | 2 |
| Linguistics | 0 | 0 | 2 | 0 | 8 | G 2 | 12 |
| Psychology | 0 | 0 | 0 | 0 | 7 | G 0 | 7 |
| Philosophy | 0 | 0 | 0 | 1 | 3 | G 0 | 4 |
| Management | 0 | 4 | 1 | 8 | 100 | G 16 | 129 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Science | 0 | 23 | 34 | 27 | 197 | G | 8 | 289 |
| Physics | 0 | 13 | 12 | 14 | 54 | G | 3 | 96 |
| Mathematics | 0 | 4 | 16 | 4 | 26 | G | 0 | 50 |
| Nutrition | 0 | 0 | 0 | 0 | 32 | G | 2 | 34 |
| Chemistry | 0 | 2 | 2 | 1 | 33 | G | 0 | 38 |
| Biology | 0 | 4 | 4 | 8 | 11 | G | 1 | 28 |
| Meteorology | 0 | 0 | 0 | 0 | 10 | G | 2 | 12 |
| Earth and Planetary Sciences | 0 | 0 | 0 | 0 | 31 | G | 0 | 31 |
| TOTALS: | 80 | 94 | 104 | 125 | 899 | U(7) | 87 | 1,396 |

## Educational Council

This is the twentieth annual report on the activities of the Educational Council. In that twenty-year period the Council has grown to almost 1,000 members in 46 states, 1 territory, and 32 foreign countries. Council Members now are assigned to over 2,500 secondary schools on a contact basis. Each year they conduct over 2,500 interviews on final applicants. Throughout these 20 years of growth, the aims of the Council remain unchanged. The members serve as the source of up-to-date information about M.I.T. and science and technology to their local schools, students, and communities. A second, no less vital role, is their direct contact with over 80 percent of the applicants for admission. They are, as representatives of M.I.T.'s Admissions Office, evaluators of and counselors to the students. They bear heavy responsibility for the impression of M.I.T. in the applicant's mind. These numerous contacts by volunteer alumni with schools and individual applicants are the work of the Educational Council. The efforts described below aim to support this fundamental work of these volunteers.

Given the size, age, and nature of the role of the Council, the major task for the year lay in maintaining the high standards of the Council while continuing to narrow the gap between the impression of M.I.T. and its reality. Several approaches were used. First, major efforts continue to bring recent graduates, more women and added minority alumni, especially black Americans, into the Council membership. These efforts have depended upon the cooperation of many at M.I.T., notably the Alumni Association staff, Professor Emily L. Wick, Mrs. Dorothy L. Bowe, and John A. Mims. Second, major revisions of the Educational Council Handbook have been written and distributed to all Council Members. Third, a special Handbook for Foreign Educational Council Members was prepared with the assistance of the Foreign Student Office and distributed to overseas members. Fourth, the popular and most successful program of Faculty Lectures was continued thanks to Professors Bernhardt J. Wuensch, James W. Mar, and Robert R. Schrock, who spoke to over 1,500 students in three weeks of travel. Fifth, the Council has continued to assist and encourage coordinated contact between current M.I.T. students and applicants through E.C. and joint E.C. and M.I.T. Club sponsored meetings at Christmas and during spring vacation. Sixth, the Director conducted two special projects. The first was a review and revision of application procedures with the cooperation of the Admissions Office staff. The second is a major study of highly able high-school seniors concerning their college selection decisions. The study is being supervised by the Director with the assistance of Professor Milton Lavin and conducted under the U.R.O.P. program by three students – Joy Judell, Linda Tufts, and Randy Vereen.

Perhaps the most significant activity in support of the Council membership is the direct communications with them. This includes the E.C. Bulletin, correspondence, numerous computerized statistical reports, but, most vitally, the face-to-face communications with

groups and individuals. Toward this end over 50 regional meetings were held by the Council staff. Additional Admissions staff members held about 10 regional meetings. These educational sessions with their open-ended give and take still provide the framework for all of the communications activities. In and around these meetings, sometimes jointly with them, the Council staff also tried to assist in the maintenance of contacts with students and school personnel. In the face of a reduction in the Council staff, as William Dix, who has ably assisted us for three years, leaves to pursue graduate study, a new area plan has been devised. This plan divides the United States into nine areas and assigns travel for E.C. and school contacts, as well as school and student correspondence, to a staff member of either the Admissions Office or the Council Office. Central responsibility for Council support is retained by the Council Office. The area staff member will travel to his or her area over a period of several years to conduct E.C. meetings and contact schools and students. It is expected that this continuity will bring greater efficiency and sensitivity into our relationships with Educational Counselors, schools, and students.

WILLIAM J. HECHT

## Office of Student Financial Aid

The year just ended has seen a significant interruption in several current trends. Despite an increase of $400 in the average student's expense budget (engendered by a $150 increase in tuition and substantial increases in room and board costs), a nominal increase in the overall financial need of the undergraduate student body (as demonstrated through applications) was observed. Indeed, financial aid in the form of scholarships and loans was awarded by M.I.T. to 2,003 needy students, nearly a 12 percent drop in numbers from last year. Related to this phenomenon, and perhaps contributing to it, was the decision this year to require aid applicants' parents to submit a copy of their Federal income tax return in support of the aid application.

The average need of aid recipients in this year was $2,740 compared with $2,390 last year – the difference of $350 (against the budget rise of $400) indicating that the capability of families to pay the cost of education here is not keeping pace with the rise in that cost.

Significant increased aid resources materialized in the form of an unusually large National Defense Loan allocation that allowed a 70 percent increase in loans from this fund over last year; and a 20 percent increase in investment income associated with the scholarship endowment. The latter was offset by a reduction in the availability of unrestricted operating income, with none being allocated for regular scholarship awards, and by a drop in outside scholarship support. Thus, aid resources again did not meet the demand, as anticipated, and each aid recipient was asked to work during the school year or to seek additional loan funds from outside M.I.T. The average scholarship grant awarded was $1,480 compared with $1,420 last year for needy recipients. The average loan was $975, indicating a resumption of the rising average debt incurred by our aid recipients (last year's average was $930).

Tables I and II accumulate the statistics for the year.

### Scholarships

Direct grants to needy students from outside agencies continue to drop – a total of $539,651 was received this year versus $646,224 last year. A very significant increase was seen, on the other hand, in outside aid to students who did not ask M.I.T. for help or who were judged not to need it. A total of $526,487 was received this way against $242,200 last year -- this form of aid seems to be rising quite rapidly, representing an interesting displacement in the pattern of financial aid at M.I.T.

The investment income on the scholarship endowment yielded $1,657,593, an increase of 20 percent over last year's figure. Thanks to vigorous support by the education community, in which this Office had a small part, the Commonwealth of Massachusetts expanded its program of scholarships for residents, and M.I.T. enjoyed the benefit of a substantial increase in these awards. Despite this windfall, the total received in annual "gift" scholarships (from foundations, government agencies, corporations and individuals) dropped 10 percent from $502,659 to $452,538. The special scholarship program for first-and second-year minority-group students entailed the use of $146,200 in special scholarship awards to substitute for a portion of the usual loan-and-job package in M.I.T.'s awards.

The total used to provide scholarships to needy undergraduates was $2,795,982, a decrease of 6.5 percent from last year's figure. In addition, 333 students received $526,487 in scholarship awards unrelated to need, from agencies outside M.I.T.

During the year, the scholarship endowment was increased by the establishment of ten new funds. These represented an increase of $412,502 in endowment, and the total principal in these funds is now $19,521,016.

## Loans

The increased allocation of National Defense Loans made it possible to fund 75 percent of the undergraduate loan awards from this source (a total of $1,261,822), and allowed the Office to award an additional $434,685 in National Defense Loans to graduate students. Undergraduates also borrowed $311,155 from the Technology Loan Fund and $130,975 from other M.I.T. funds, principally those which M.I.T. borrowed from commercial sources and reloaned under the government's guaranteed loan program.

The total loaned by M.I.T. to graduate students was $695,586, an increase of 35 percent over last year. Sixty-three percent of that amount, or $434,685, came from National Defense funds; $211,501 came from the Graduate Loan Fund (most to foreign students), and the relatively small balance, $49,400, from Federally guaranteed loans awarded by M.I.T.

The year was characterized by intense interest and activity, both at M.I.T. and on a national scale, in the area of student loans. Other schools facing the problem of need out-stripping resources have cast about for ways to fill the gap and are arriving at loans as the only solution. M.I.T., of course, has been in the business of student loans for 40 years, and they are a fact of life in its aid program. Nevertheless, M.I.T. also perceives that a massive influx of new aid resources will be necessary over the next several years if the Institute is to continue its policy of providing financial aid to those students who demonstrate the need for it. In an attempt to find these new resources, M.I.T. has placed student financial aid in the position of highest priority in its search for funds for urgent needs, and hopes to be able to make available $10 million in new student aid money over the next five years. It is expected that most of the new money received will augment the loan program, and it also is expected that the Office will be even more dependent upon student loans than in the past.

In view of the role of loans in the future, an Institute task force during the year was charged with reviewing the student aid program generally and the role of student debt in particular. In the spring a proposal for revision in the terms of administration of the Technology Loan Fund was presented, which has met with general approval throughout the Institute and which will be implemented in the coming year. Its essential features include repayment schedules related to M.I.T. graduates' probable earning power, and the use of the Federal government's Guaranteed Loan Program as an integral part of the Technology Loan Fund.

## Employment

Once again this year, the tradition of working to acquire part of the means to pay for their education was carried on by students at M.I.T. Approximately 2,200 aid recipients and non-aid recipients found employment on campus during 1971-72, thereby acquiring gross earnings of $1,800,000, including nearly $400,000 under the Federal College Work-Study Program -- in its second year at M.I.T.

Students worked at customary tasks in dining halls, dormitories, laboratories, libraries, and offices, and many participated in a new employment program designed to link undergraduates with research activities conducted by faculty and staff members. Individual earnings during the nine-month academic year covered a wide spectrum, but the average income for a typical 12-hour-per-week job was $700-800.

## Staff

During the year two new Assistant Directors joined the Office of Student Financial Aid staff -- Dorothy Bowe, formally a member of the Office of the Dean for Student Affairs, and Lawrence E. Maguire, who came from the Fiscal Planning Office. Lawrence A. Hough resigned as Assistant Director to take a position at Stanford University. Retiring this year was Dorothy Hughes, who served the office well for 18 years.

TABLE I Undergraduate Scholarships and Loans--1971, 1972

| | 1972 | 1971 |
|---|---|---|
| SCHOLARSHIPS WITHIN NEED | | |
| From M.I.T. endowment funds | $1,657,593 | $1,378,475 |
| From M.I.T. operating funds | -- | 325,400 |
| From gift scholarships | 452,538 | 502,659 |
| Direct to students | 539,651 | 646,224 |
| Special program scholarships | 146,200 | 142,450 |
| Total scholarships | $2,795,982 | $2,995,208 |
| Number of recipients | 1,892 | 2,115 |
| EDUCATIONAL LOANS WITHIN NEED | | |
| Technology Loan Fund | $ 311,155 | $ 362,684 |
| National Defense Student Loans | 1,261,822 | 995,929 |
| Other M.I.T. loan funds | 130,975 | 151,585 |
| Total loans | $1,703,952 | $1,510,198 |
| Number of recipients | 1,745 | 1,731 |
| TOTAL AID WITHIN NEED | $4,499,934 | $4,505,406 |
| Number of recipients | 2,003 | 2,270 |
| TOTAL DEMONSTRATED NEED | $5,494,232 | $5,424,350 |
| SCHOLARSHIPS RECEIVED BEYOND NEED | | |
| Direct to students | $ 526,487 | $ 242,200 |
| Number of recipients | 333 | 153 |

| | 1972 | 1971 |
|---|---|---|
| LOANS RECEIVED FROM OUTSIDE SOURCES | $ 507,965 | $ 398,818 |
| Number of recipients | 450 | 367 |
| FACULTY AND EMPLOYEE CHILD BENEFITS | -- | $ 49,252 |
| Number of recipients | -- | 26 |
| Total scholarship and loan aid | $5,534,386 | $5,195,676 |
| Number of recipients | 2,541 | 2,597 |

TABLE II Summary of Loan Awards, Graduate and Undergraduate 1971, 1972

| | 1972 | 1971 |
|---|---|---|
| FROM M.I.T. SOURCES | | |
| Technology Loan Fund | $ 311,155 | $ 362,684 |
| Other M.I.T. loan funds | 74,925 | 70,225 |
| National Defense Student Loans | 1,696,507 | 1,003,229 |
| Ford Forgivable Loans | 0 | 20,280 |
| Graduate loan fund | 275,327 | 392,599 |
| Federally guaranteed loans | 105,450 | 279,260 |
| Subtotal | $2,463,364 | $2,128,277 |
| Number of recipients | 2,121 | 2,034 |
| FROM OUTSIDE SOURCES | $ 638,950 | $ 552,418 |
| Number of recipients | 545 | 480 |
| TOTAL EDUCATIONAL LOANS | $3,102,314 | $2,680,695 |
| Number of recipients | 2,620 | 2,471 |
| SPECIAL LOANS | | |
| Short-term loans | $ 115,839 | $ 106,670 |
| Number of recipients | 373 | 304 |

JACK H. FRAILEY

## Career Planning and Placement Office

The economic recession whose effects were first felt in the 1969-70 academic year continued to leave its mark on the work of the Office in 1971-72. The number of companies and government agencies coming to interview graduating students dropped by 17 percent, following a drop of 24 percent the previous year. It was again the case that most alumni registering with the Office were out of work, or feared that they soon would be. Alumni registrants totaled 705 over the course of the year, a significant drop from the 972 that turned to the Office for help in 1970-71, but still a high figure. One must go back a decade to the recession

years of the late fifties and early sixties to find a run of years when alumni registrations continued so high. The activity of the Office in 1971-72 was a faithful indicator of the state of the economy, along with such measures as freight-car loadings, machine-tool orders, and the price of gold.

Fortunately, the last months of the year brought signs of an upturn. A number of companies which had not expected to have vacancies to fill made last-minute arrangements to recruit. A reassuring number of students had problems choosing among job offers. Companies inquiring about starting salary rates reported that they were beginning to face competition for the candidates they wanted. The drop in alumni registrations also pointed to better times.

In 1970-71 the response of many students and alumni to the depressed job market was one of anger and bitterness. This past year their mood was rather one of resignation. Students and alumni seemed prepared to accept that they were in a new game, with new rules. There was again a drop in the number of students seeking interviews with companies, although not so large a drop as in 1970-71. One hesitates to fault the students for not pursuing more ardently the jobs company and government recruiters had to offer. After reading Richard B. Freeman's (The Market for College Trained Manpower - A Study in the Economics of Career Choice, Harvard University Press, 1971) illuminating analysis of the responsiveness of students to market conditions, one is inclined to respect their realism. They looked elsewhere to market their aptitudes and skills.

Where then did they turn? The information collected does not provide a simple answer. An unprecedented number of students have been accepted to medical school and a considerable number to law school, but the total of all students going to graduate school has not changed markedly from 1970-71. Students choosing medicine and law have turned their backs on graduate study in the arts and sciences as well as on employment in industry and government. However, some developments stand out. For one, there was a noticeable increase in 1971-72 in the number of graduating Ph. D.'s taking postdoctoral fellowships and assistantships. It is a paradoxical phenomenon, if one considers that most postdoctoral appointments are Federally funded since the past year was not a vintage year from the point of view of Federal support of research. The increased number of students taking postdoctoral positions has made many wonder what happens to postdoctorals when their appointments end, and in May a questionnaire was sent to postdoctorals at M. I. T. whose appointments were due to run out with the end of the academic year. It is hoped that the data collected will be the start of a continuing series on this subject.

Another noticeable change is an increase in the number of foreign students going home after graduation. The change does not make an important difference at the undergraduate level, where foreign students constitute only a small percentage of the student population, but it is important in the graduate school where a quarter of all degree candidates are from abroad. Since February, 1971, the U. S. Department of Labor has restricted severely the opportunity for foreign students to remain in the country after graduation and the opportunity for domestic companies to hire them. The situation is a far cry from that existing less than three years ago, when the next stops on the schedule of one recruiter who visited M. I. T. were universities in Europe. Then, foreign students constituted a significant fraction of all M. I. T. students entering industry. Now, domestic companies are almost totally barred to them.

While many students undoubtedly had great difficulty finding acceptable jobs, unemployment among graduating students remained low. Some students considered radical changes in their career plans -- a physics Ph. D., for example, talked of switching from cryogenic research to securities analysis -- but, whatever the proposed career, students insisted on jobs in the mainstream and were not content to drift into a backwater. If one looks to see where individual students went, whether to jobs in business, government, or the universities, the institutions concerned are familiar names, widely known and respected. Candidates retained

a healthy discrimination in choosing employment.

Several enquiries during the year were received from employers interested in hiring minority students and women. In the fall a distinguished black alumnus was invited to talk with black students about the experiences of a black graduate in industry. A large group of students turned out for the meeting. The meeting encouraged black students to turn to the Office as a friendly resource and the Office was able to help a number of graduating black students as they considered the variety of employment opportunities open to them. The Director was invited to speak to a meeting of the Women's Forum at M.I.T., and the Office took a number of steps to assist the cause of women graduates. The Office is delighted to work with employers implementing affirmative action programs and looks forward to increasingly close cooperation with employers in this area in the years ahead.

The past academic year saw a number of important staff changes in the Office. Most important was the retirement on October 31, 1971, of Evelyn Yates after 29 years as Alumni Placement Officer. She came to M.I.T. in 1942 from the Placement Office at Wellesley College. She established one of the best alumni placement services in the nation. During her years at M.I.T. more than 160,000 positions were listed with her by untold companies, and some 20,000 alumni turned to her for help, often again and again. In 1967 she was elected an honorary member of the M.I.T. Alumni Association. Kathleen Gallery, who joined the Office in February, 1970, as Assistant Alumni Placement Officer, now has prime responsibility for alumni placement. Linda Stantial has succeeded Miss Gallery as Assistant Alumni Placement Officer. To help the Office make an extra effort for alumni during a year when too many careers were in jeopardy, Jay C. Hammerness came in November from the Office of the Dean for Student Affairs as a Special Assistant in the area of alumni placement.

ROBERT K. WEATHERALL

# Vice President for Research

Research at M. I. T. experienced real growth for the first time since 1968 in the year ending June 30, 1972. Volume on the campus will approximate $70 million on a gross basis, about $65. 5 million net of industrial subcontracts, comparable to $60. 3 million in the previous year. The Vice President for Research looks for an additional increase next year to a net total of about $73. 6 million. More detail on the activities that comprise the campus research program will be found in the Provost's section of this report.

At Lincoln Laboratory volume increased to $68. 0 million, about 16 percent higher than last year, and will in all probability climb to $72. 0 million next year. Draper Laboratory also experienced an increase of about 11 percent over last year. Its affairs are reported in a separate section, in keeping with its status as a separate division of the Institute governed by its own Board of Directors.

An administrative change just recently announced and effective on July 1, 1972, involves the transfer of responsibility for overseeing the operation of five large interdisciplinary laboratories from the Office of the Provost to this Office. These are: the Laboratory for Nuclear Science, the Research Laboratory of Electronics, the Francis Bitter National Magnet Laboratory, the Center for Space Research, and the Center for Materials Science and Engineering. In addition, M. I. T. 's part of the responsibility for the direction of the Cambridge Electron Accelerator, which is managed jointly with Harvard University, was also transferred to the Vice President for Research.

For the Lincoln Laboratory the year was tranquil, saw steady and significant technical progress, and was highlighted by the initiation of a major new program in air traffic control. The principal program areas continue to be communication and strategic technology, with other significant efforts in advanced electronic technology, radar techniques, and seismic discrimination. These programs continue essentially unchanged in scope.

The number of new programs being undertaken by the Laboratory is growing, both in terms of size and variety -- a very encouraging trend. The major new air traffic control program mentioned above is under Federal Aviation Administration sponsorship and calls for the Laboratory, over the next five years, to act as the primary technical agency in the development of a Discrete Address Beacon System which will upgrade existing air traffic control system capabilities substantially. This program, taken together with other civilian air traffic control activities, now comprises about 15 percent of the Laboratory's total effort.

The Ambulatory Health Care program continues to progress. Procedures designed to permit para-medical personnel to play a larger role in the delivery of health care have undergone successful experimental testing in clinical environments, specifically in the management of diabetes and hypertension and in the treatment of patients with upper respiratory complaints. A self-paced learning system developed by the Laboratory and now under test at Keesler Air Force Base indicates an ability to cut training time by one-third over conventional methods, with a uniformly high degree of enthusiasm on the part of the students.

During the year Walter E. Morrow, Jr. was appointed Associate Director of the Lincoln Laboratory and Daniel E. Dustin joined Henry W. Fitzpatrick and Jerome Freedman as an Assistant Director.

In the area of research policy, the principal focus has been on stimulation of the process of innovation and on mechanisms for quickening the transfer of technological advances from laboratory to general public use. The most significant manifestation of this effort was the founding of a new corporation, chartered by the Commonwealth of Massachusetts on April 3, 1972, called the M. I. T. Development Foundation, Inc. The new organization is experimental in nature, will serve to assist in the formation of new enterprises, and will provide a communications link between government, industry, and sources of venture capital interested in the development and application of technology at M. I. T.

Four initial directors have been appointed by M. I. T. 's Executive Committee. They are Carl M. Mueller, senior partner, Loeb, Rhoades & Co. of New York; Richard S. Morse, Senior Lecturer in the Sloan School of Management; Samuel W. Bodman III, vice-president, Fidelity Management and Research Co. of Boston; and the undersigned. Mr. Morse has been elected president of the new corporation. Still pending is an anticipated favorable ruling by the Internal Revenue Service on the tax-exempt status of the new organization.

The Institute's Committee on Inventions and Copyrights was active in the same general area, and a number of changes were effected. It approved new incentives for the industrial sponsors of research at M. I. T. which are set forth in detail in the report of the Division of Sponsored Research. Also approved was a new patent agreement for members of the research staff, which gives rights of ownership of their inventions to such individuals when certain conditions are satisfied. Formerly these staff members had no such rights. The Committee also agreed to recommend a new royalty-sharing agreement with Institute inventors. Among items still being considered is a new policy on copyrights.

The reorganization of the Institute's patent section is complete. Patent filing and patent licensing have been combined. The reduction of in-house patent counsel has been completed, and initial reaction of the Institute community to interacting with selected outside counsel has been very favorable.

Finally, this Office is very please to report that Dr. Emanuel R. Piore, who retired in mid-year as Vice President and Chief Scientist of the IBM Corporation, has accepted an appointment as Consultant to the President of the Institute and is working closely with this Office on a variety of research related problems.

ALBERT G. HILL

## Charles Stark Draper Laboratory

June 1, 1972, marked the completion of Draper Laboratory's second year as an independent division of the Institute, and a major portion of the attention and effort of the Board of Directors and Officers continues to be directed toward the very complex business of designing an effective method of divesting the Laboratory from M. I. T. Progress is being made and is discussed further on in this report.

Operationally it was a very sound year for the Laboratory. Research volume will approximate $50 million, an increase of 11 percent over last year's total of $44 million. Projections for fiscal year 1973 indicate an expected level of about $60 million, but a substantial part of the anticipated increase will flow through the Laboratory to industrial subcontractors. Laboratory personnel probably will increase by about 100 from the present level of 1, 700.

During this past year the distribution of Laboratory sponsorship was 67 percent military, 31 percent National Aeronautics and Space Administration (NASA), and 2 percent other. For the forthcoming year military sponsorship will account for about the same fraction of Laboratory research, NASA programs will decline modestly, and other programs will increase to about 3 percent of the total. The level of "other" programs in absolute terms remains modest, but the increasing trend is heartening. There continues to be a broadening of the base of applications for the Laboratory's technological capabilities. Continued growth in biomedical engineering, for example, has been recognized by the establishment of a new organizational entity within the Laboratory -- the Division of Medicine, Biology, and Health Care Programs. Other involvements in oceanography, industrial process control, and medical instrumentation, to cite but a few, continued to flourish and give great future promise.

Education, particularly in a real-world environment, has been of paramount interest in the Laboratory since its inception and will continue to be in the future. To enhance and expand educational activites, a new Division of Education has been formed within the Laboratory which, among other purposes, will seek to establish ties with institutions in addition to M. I. T. which can benefit from the unique resources and capabilities of the Laboratory.

The Laboratory's efforts to develop pioneering concepts into operating instruments continue. Engineering models of the third generation inertial sensors are undergoing extensive testing, and results to date give promise that within two years these high-performance instruments will be available for incorporation into Laboratory developed systems. The potential application of such systems is enormous.

While the work of the Laboratory went on, in keeping with its traditional high standards, significant progress toward achieving its separation from M. I. T. has been made. As this is being written the Laboratory is close to agreement with the Federal government agencies who sponsor research on the campus, at Lincoln Laboratory, and at Draper Laboratory on the financial implications of divestment to both M. I. T. and the Laboratory.

As background to an understanding of the nature of this agreement, an explanation of these implications is necessary. The Laboratory contracts this year provided about $10 million in revenues to meet its proportionate share of M. I. T. 's indirect expenses of operation. When it is divested these revenues will disappear, but only about $5 million in indirect cost savings can be realized. A $5 million additional burden on M. I. T. 's general funds would be intolerable. The Federal government, recognizing this, will agree to an arrangement whereby this residual unfunded indirect expense will be apportioned as follows: $2 million to be borne by campus research, $1 million by Lincoln Laboratory, and $1 million by the Institute. The remaining $1 million would be offset by income from the independent Draper Laboratory, representing rental of laboratory space in M. I. T. owned buildings, use of Institute facilities (athletic, dining, libraries, etc.), and M. I. T. services furnished it (e. g., medical).

The agreement also recognizes and sanctions a financial structure for the proposed new not-for-profit corporation adequate to permit the Laboratory to assume new and necessary functions and to carry out a program of independent research. The target date for implementation of the agreement is July 1, 1973.

It must be emphasized that this pending agreement is just a first step. It can be likened somewhat to obtaining a hunting license which sanctions the hunt but in no way guarantees its success. Yet to be ascertained is the ability and/or willingness of the Federal sponsors to provide additional funds to offset the increased burden of overhead to be assumed by campus and Lincoln Laboratory research grants and contracts. If this obligation has to be met by a matching reduction in direct effort, the impact would be serious. Relative

to the new corporation, the ability to negotiate a necessary and adequate fee on its contracts is an unknown. Such negotiations will have to be on a contract-by-contract basis, a process that will require up to six months to complete. Another factor is the ability to negotiate an arrangement for advance payments on contracts, which is the only viable way the new corporation can meet its working capital needs.

In summary, a vital first step has been taken; several equally vital ones are ahead. It also should be remembered that in no small part the deliberate character of the process of separation is due to strong and sincere interest on the parts of both the Institute and the Laboratory that the divestment not impair their ability to interact beneficially in the future.

No significant personnel changes took place during the year, apart from the resignation from the Board of Directors of Dr. Carl Kaysen and the election of General Robert A. Duffy, who assumed duties as Vice President of the Laboratory.

ALBERT G. HILL
C. STARK DRAPER

## Division of Sponsored Research

During the past year, one of the most apparent trends in on-campus sponsored research has been the Institute's growing involvement in research related to health and to the solution of other pressing national needs. Several major new research facilities and programs reflect this trend, as does the rapid increase of research support from the Department of Health, Education, and Welfare and from the National Science Foundation. Although this has resulted in the first "real" growth in campus research over and above inflation in four years, it has not yet provided sufficient support for research assistants to compensate for the continuing decline in support for fellows and trainees.

### New Research Activities

Of the new research activities and programs established during the year, the following are representative.

In March, the recently formed Harvard-M.I.T. Program in Health Sciences and Technology received its first major research support, a $5 million five-year grant from the National Heart and Lung Institute for a multi-disciplinary program of research on biomedical materials. Directing the biomaterials program will be Robert W. Mann, presently Germeshausen Professor at M.I.T., who expects that the effort will become a principal focus of research on natural biological materials and synthetic substitutes in the university-hospital community in Boston and nationally.

At formal ceremonies held in April at Middleton, Massachusetts, the Institute's 400 million volt linear accelerator was named formally in honor of the late U.S. Representative William Bates. The accelerator is being constructed at a total estimated cost of $7 million, of which $5.7 million was provided by the Atomic Energy Commission, with the balance of $1.3 million coming from M.I.T. It will be used by scientists from M.I.T. and other universities and laboratories throughout the country to probe the structure and fundamental properties of the atomic nucleus. Construction of the facility began in 1966, and a major development milestone was reached last December when a 20 million electron volt (mev) beam was achieved. Although a fraction of the full 400 mev goal, this demonstrated design and component feasibility.

Also in April, the Center for Policy Alternatives was established in the M. I. T. School of Engineering to foster the application of technology to the solution of social problems, with Dr. J. Herbert Hollomon appointed the Center's first director. The purpose of the Center is to study and investigate substantive issues related to society, particularly those in which technology and engineering could play significant roles.

## Research Volume

The total volume of sponsored research performed in fiscal year 1972 by academic departments and interdepartmental laboratories (excluding major subcontracts) exceeded $65,435,000, compared with $60,336,000 in 1971 and $57,713,000 in 1970. This represents an 8.5 percent increase over fiscal year 1971, the first "real" growth over and above inflation in four years. In addition, the preliminary estimate of research volume in fiscal year 1973 (excluding $1.7 million in subcontracts) is $74,132,000, an increase of 13.3 percent. This estimate reflects the first full year of operations at the LINAC facility in Middleton, Massachusetts; a significant expansion of health related programs, including biomaterials and cancer research; and programs involving child health and environmental health sciences. These health programs will increase HEW sponsored research volume from $11.3 million in fiscal year 1972 to $14.3 million in 1973.

Increased support from the National Science Foundation in 1972 included a number of new programs involving research applicable to the solution of national problems. In addition, the Foundation, which in fiscal year 1972 succeeded the Air Force in providing the principal support for the National Magnet Laboratory, will in fiscal year 1973 assume sponsorship of the Center for Materials Science and Engineering, formerly supported by the Advanced Research Projects Agency (ARPA). This and other expanded NSF support will increase NSF volume from $10.8 million in 1972 to $16.8 million in 1973.

## Student Support Programs

In fiscal year 1972, approximately 456 fellows and trainees at M. I. T. received $2.3 million in Federal support independent of specific research projects, compared with 600 students who received over $2.8 million in 1971. In addition, approximately 175 trainees were supported in 1972 on NIH research training grants included in research volume, compared with 160 in 1971.

The administration's decision to reduce Federal support for training in science and engineering will be felt further in fiscal year 1973 as the number of fellows and trainees declines to an estimated 330, with roughly $1.7 million in support. The number of NIH trainees may remain stable.

It is not yet apparent that loss of fellowship and traineeship support can be offset by increased support for graduate research assistants. In 1972, research assistant salaries were approximately $6,020,000, paid to 1,000 graduate students. The projected research assistant support of $6,300,000 in 1973 represents no real increas in view of salary increases effective in June, 1972.

The passage of the Higher Education Opportunity Act in June, 1972, represents one of the most significant developments in the history of Federal support for education. It not only extends existing student financial aid programs, but also authorizes for the first time Federal grants for general institutional assistance. The student assistance provisions tend to direct Federal funds first and in the largest amounts to the neediest students, and the general institutional assistance provisions are based primarily on the number of needy students and the dollar amount provided them. The implications of this in terms of support for middle-income students, and the question of how much general institutional assistance will result from the complex

provisions, will not be known until legislation covering appropriations has been introduced, debated, and enacted.

## Organizational Changes

In June the Office of the President and Chancellor announced the transfer of administrative responsibility for the following laboratories from the Provost's Office to the Vice President for Research, Dr. Albert G. Hill: Center for Materials Science and Engineering, Center for Space Research, Francis Bitter National Magnet Laboratory, Laboratory for Nuclear Science, and Research Laboratory of Electronics. In addition, M.I.T.'s part of the responsibility for the direction of the Cambridge Electron Accelerator, which is managed jointly with Harvard University, also was transferred to the Vice President for Research.

Within the D.S.R. Office a number of personnel changes reflect the normal interaction between D.S.R. and the academic departments and laboratories, which provides a continuing opportunity for broader experience and career development. Roger P. Webber, who has been with D.S.R. for over 21 years, transferred to the position of Fiscal Officer at the Center for Space Research, and Kenneth M. Campbell transferred from the D.S.R. procurement section to similar duties at the Center. Accepting appointments as Assistant Directors in D.S.R. were Frederick C. Bentley II and Joseph F. Connolly, formerly administrative officers of the Department of Nutrition and Food Science and the Joint Center for Urban Studies, respectively.

Two promotions to new positions within D.S.R. also were announced this spring. Carol E. Van Aken and Paul H. Quinn were appointed Research Coordinators, a new title used to designate individuals who will have coordinating responsibility for major areas of research administration. Ms. Van Aken will provide liaison between D.S.R. and the Office of the President and Chancellor, the Vice Presidents, and other offices of administration. Mr. Quinn will provide administrative assistance in the establishment of major new facilities devoted to health related research.

GEORGE H. DUMMER

# Vice President and Treasurer

1971-72 was a year of constructive developments in the finances of the Institute. Funds for the long-term support of operations continued to increase, further additions were made to the educational plant, a substantial program of scholarships, fellowships, and student loans was financed, and the use of unrestricted resources to fund operations was reduced from the preceding year. The positive financial results for the year reflected increased tuition revenues and endowment income, an expansion in government sponsored research, early indications of the additional steps taken to control costs, and the receipt of major gifts, grants, and bequests from alumni and friends of M.I.T. and from private foundations and industry.

Unrestricted resources of $1,593,000 were used to meet the gap between revenues and expenses in 1971-72, compared to $4,907,000 in 1970-71. Special factors accounted for the greater part of the lower operations requirement for unrestricted resources. During the latter part of the fiscal year 1970-71, a substantial portion of the bequest of K. Dexter McCormick was added to general endowment. This endowment produced additional investment income of $788,000 in 1971-72 that in the preceding year was classified as unrestricted resources applied to operations. In 1971-72, the Institute concluded negotiations for indirect expense recovery on sponsored research for the fiscal years 1969, 1970, and 1971, with nonrecurring revenues generated and allocated to operations for the year ended June 30, 1972, of $1,046,000.

The decrease in instruction and unsponsored research from $27,918,000 in 1970-71 to $26,976,000 in 1971-72 was occasioned largely by the decrease in the use by the academic departments of gifts, investment income, and receipts for restricted purposes from $9,621,000 to $7,878,000. However, restricted gifts and grants received for departmental activities increased over 1970-71. The pattern of leveling and decreasing direct expenses for sponsored research in 1970-71 was reversed in 1971-72 with the direct expenses for departmental and interdepartmental research and the special laboratories at a higher level, but with most of the increase for the special laboratories associated with greater outlays for materials and services and subcontracts to outside organizations.

## Gifts

Gifts, grants, and bequests received in 1971-72 and in 1970-71 were as follows:

| | 1971-72 | 1970-71 |
|---|---|---|
| Gifts for endowment | $ 2,680,000 | $ 3,863,000 |
| Gifts for buildings | 2,415,000 | 2,515,000 |
| Gifts for current use -- invested | 6,172,000 | 24,215,000 |
| Industrial Liaison Program | 1,359,000 | 1,405,000 |
| Other funds for current use | 5,814,000 | 3,593,000 |
| Total gifts to funds | $18,440,000 | $35,591,000 |
| Grants-in-aid | 3,609,000 | 4,046,000 |
| Total | $22,049,000 | $39,637,000 |

The decrease in "Gifts for current use -- invested" and the decrease in total gifts in 1971-72 from 1970-71 was due almost entirely to a very large receipt under the legacy of K. Dexter McCormick in 1970-71. Of the total unrestricted gifts and bequests of $3,556,000 received

in 1971-72 from individuals and estates, $2,479,000 were represented by bequests from William C. Potter '97, Harry B. Hunt '97, John R. Macomber '97, and from Etta M. Burgess, whose brother, Frank L. Cobb, was a member of the Class of 1910. Gifts and bequests for professorships and for student aid made up a large part of the increase in endowment for 1971-72. Support for the Health Sciences and Technology Program and the Electrical Engineering and Electronics Complex is included in "Gifts for current use -- invested" and in "Gifts for buildings." Large private foundation grants for research were received during the year and are represented in "Other funds for current use." Unrestricted gifts of $813,000 are included in the total of $2,792,000 reported by the Alumni Fund in 1971-72.

## Funds

The total book value of the funds of the Institute on June 30, 1972 was $335,318,000, compared with $328,247,000 on June 30, 1971.

| Endowment funds: | 1971-72 | 1970-71 |
|---|---|---|
| For general purposes | $ 74,199,000 | $ 73,479,000 |
| For designated purposes | 108,326,000 | 104,164,000 |
| Net realized gain from investments | 39,302,000 | 38,721,000 |
| Total endowment funds | $221,827,000 | $216,364,000 |
| Building and expendable funds | 75,489,000 | 75,084,000 |
| Other funds | 38,002,000 | 36,799,000 |
| Total funds | $335,318,000 | $328,247,000 |

Endowment funds in 1971-72 were increased by additional capital for faculty salaries, for undergraduate scholarships, and funds for the support of the academic departments and research. Net realized gains on the general investments for the year were $764,000, compared with $7,650,000 in 1970-71 and $3,979,000 in 1969-70.

$966,000 of net patent revenues and $931,000 from the net use of facilities revenues derived from sponsored research, together with $3,556,000 of gifts and bequests for general purposes, provided $5,453,000 as an addition to the unrestricted resources for the year. Of this total, $2,911,000 was used for operations, for student aid, and for recurring capital charges in 1971-72, and after June 30, 1972, $1,000,000 was set aside for building modernization, $1,500,000 was transferred to endowment, and the remainder was set aside for other purposes.

Investment income for distribution to funds was $20,566,000 on June 30, 1972. The principal of the Alfred P. Sloan Fund for Basic Research in the Physical Sciences was $18,361,000. The Research Reserve to support tenure salaries increased from $9,849,000 to $10,341,000 in 1971-72 because the investment income earned thereon was added to the fund. Deferred charges, inventories, and other assets including cash advances decreased during the year, releasing funds for productive investment that earlier were dedicated to interim financing requirements. With the growth in the funds of the Institute from $134,875,000 in 1963 to $335,318,000 in 1972, better than two-thirds of the funds have been accumulated in the last ten years.

## Plant

The book value of the educational plant of the Institute increased to $157,651,000 on June 30, 1972, from $143,120,000 on June 30, 1971, and $136,926,000 on June 30, 1970. Major additions to the educational plant included the partial construction of the Electrical Engineering and Electronics Complex, the Westgate II housing for graduate students, the concluding stages of renovations of Burton-Conner House, the construction of the J.B. Carr Indoor Tennis Center, and the George R. Wallace, Jr., Astrophysical Observatory in Westford, Massachusetts.

The increase in mortgage bonds and notes payable from $14,161,000 at June 30, 1971, to $17,649,000 at June 30, 1972, reflected the progress of construction on Westgate II and the

additional funds received from the Massachusetts Health and Educational Facilities Authority to fund this construction.

At June 30, 1972, approximately 11 percent of the book value of the plant of the Institute was funded by loans from the Federal government, through Massachusetts agencies, and from private sources. The total mortgage indebtedness of $17,649,000 is made up of $11,124,000 of Federal government loans and $6,525,000 of loans from other sources. Advances from current resources for construction were $6,270,000 on June 30, 1972, and $4,648,000 on June 30, 1971.

Funding of the construction and maintenance for ten years of the Electrical Engineering and Electronics Complex was more than 80 percent completed at the end of June, 1972, with $12,306,000 received for the building and related costs to that date, and $2,875,000 outstanding in pledges receivable, a total of $15,181,000 covering this addition in progress to the educational plant.

## Investments

The year-to-year change in the endowment and other investments of the Institute reflected higher market values for investment securities.

| | June 30, 1972 | | June 30, 1971 | |
|---|---|---|---|---|
| | Book | Market | Book | Market |
| General investments: | | | | |
| Fixed income | $145,998,000 | $138,106,000 | $144,931,000 | $132,195,000 |
| Equities | 96,611,000 | 207,991,000 | 87,287,000 | 174,479,000 |
| Real estate: | | | | |
| For present or future Institute use | 16,158,000 | 16,158,000[1] | 16,197,000 | 16,197,000[1] |
| Other real estate | 28,117,000 | 31,270,000[2] | 26,633,000 | 30,200,000[2] |
| Total | $282,884,000 | $393,525,000 | $275,048,000 | $353,071,000 |
| Separately invested | 29,404,000 | 31,877,000 | 28,239,000 | 29,468,000 |
| Students' notes receivable | 14,194,000 | 14,194,000 | 12,889,000 | 12,889,000 |
| Total | $326,482,000 | $439,596,000 | $316,176,000 | $395,428,000 |

1 At cost
2 At values determined by professional appraisers

The market value of both the fixed income securities and the equities improved markedly during the year. Common stocks at market values on June 30, 1972, were better than two-thirds of the endowment investments included within the total of general investments. Real estate investments are largely equity commitments.

The total income on the investment portfolio was $16,942,000 compared with $15,498,000 in the preceding year. The increase was due in part to the growth in endowment resources and the reinvestment of the proceeds from the sale late in 1970-71 of real estate previously not producing current income. Both the bond portfolio and the common stock portfolio yielded higher income than in the preceding year.

The general investment income distributed to funds was $16,596,000 in 1971-72 compared with $15,536,000 in 1970-71. Included therein was an increase in the use of endowment funds for operations of $9,602,000 in 1971-72, up from $8,435,000 in 1970-71. Practically all of the investment income received in 1971-72 was set aside for operations or other purposes so that the addition to investment income for distribution to funds was $294,000,

compared with $825,000 in the preceding year and $1,733,000 in 1969-70. Real estate investments to be developed into earnings assets in the future continued to result in a loss to current endowment income in 1971-72.

## Retirement Funds

The investments of the M.I.T. Pension Association, the Supplementary Retirement Plan, and the Retirement Plan for Employees on June 30, 1972, and June 30, 1971, are presented in the following exhibit. This is exclusive of reserves in excess of $6,200,000 held by a life insurance company to provide certain benefits under the Retirement Plan for Employees.

| | June 30, 1972 | | June 30, 1971 | |
|---|---|---|---|---|
| | Book | Market | Book | Market |
| Pension Association | $ 59,795,000 | $ 64,600,000 | $ 53,370,000 | $ 54,896,000 |
| Supplementary Retirement Plan -- Fixed Benefit | 31,165,000 | 30,620,000 | 28,657,000 | 26,821,000 |
| Supplementary Retirement Plan -- Variable Benefit | 16,278,000 | 19,441,000 | 13,650,000 | 15,399,000 |
| Retirement Plan for Employees | 29,831,000 | 28,904,000 | 25,463,000 | 23,414,000 |
| Total | $137,069,000 | $143,565,000 | $121,140,000 | $120,530,000 |

The retirement plan investments are held in trust for the benefit of the staff and employees of the Institute. In 1971-72, retirement plan expense was included in operations in the amount of $8,516,000, compared with $7,293,000 in 1970-71. On June 30, 1972, unfunded prior service costs of $3,770,000 remained to be amortized over 14 years.

## General

As reported in 1970-71, the Cambridge Housing Authority, supported by the Department of Housing and Urban Development, contracted to purchase from M.I.T. three sites in Cambridge owned by the Institute and the buildings to be constructed thereon under M.I.T. auspices in the amount of over $17,000,000. During 1971-72, expenditures were $7,432,000, financed by a construction loan in this amount from the Massachusetts Housing Finance Agency.

The Institute carries an investment of $3,000,000 in the debentures of the Northgate Community Corporation, a corporation organized by the Institute to provide housing for faculty and students in Cambridge and in some nearby communities. This Corporation is currently showing operating losses which may depreciate the value of the debentures included in the investment portfolio.

The dimensions of the financial impact on the Institute of the possible divestment of the Draper Laboratory were defined more clearly during 1971-72. Further steps that must be completed to assure the long-term viability of the Laboratory as a separate organization are continuing and include the provision of working capital requirements and independent capital funds.

The administration continues to give major emphasis to the planning of operating revenues and expenses over three years into the future. Improvements in the methods applicable to these projections in 1971-72 work to strengthen the Institute's finances in the years ahead. The prudent conservation of resources, the continuation of the strong development of new resources, along with the constructive investment of endowment and the careful management of costs are regarded as fundamental to the soundness of the finances of the Institute.

JOSEPH J. SNYDER

## Sources of Revenues and Funds Used to Meet Expenses of Current Operations

for the years ended June 30, 1972 and 1971

Schedule A

| | 1972 | 1971 |
|---|---|---|
| OPERATING EXPENSES | | |
| Instruction and unsponsored research | $ 26,976,000 | $ 27,918,000 |
| Sponsored research: | | |
| Direct costs: | | |
| Departmental and interdepartmental | 56,467,000 | 49,015,000 |
| Lincoln Laboratory | 62,999,000 | 52,778,000 |
| Draper Laboratory | 38,144,000 | 34,454,000 |
| Research vacation expense | 4,020,000 | 4,139,000 |
| Research administration and general expenses | 1,366,000 | 1,562,000 |
| Total expenses directly attributable to instruction and research | $189,972,000 | $169,866,000 |
| Costs applicable to both instruction and research: | | |
| Libraries | 3,156,000 | 3,030,000 |
| Medical | 2,315,000 | 2,160,000 |
| Plant operation and maintenance | 12,517,000 | 12,384,000 |
| Administration | 2,881,000 | 2,621,000 |
| Fiscal, personnel, and other Institute-wide services | 7,792,000 | 7,518,000 |
| General expenses | 2,538,000 | 2,066,000 |
| Other instruction and research support activities | 2,428,000 | 2,718,000 |
| Student services | 4,415,000 | 4,368,000 |
| Auxiliary activities | 7,494,000 | 7,162,000 |
| | $235,508,000 | $213,893,000 |
| REVENUES AND FUNDS USED | | |
| Tuition and other income | $ 22,512,000 | $ 21,548,000 |
| Research revenues: | | |
| Departmental and interdepartmental | 69,671,000 | 60,892,000 |
| Lincoln Laboratory | 69,569,000 | 58,604,000 |
| Draper Laboratory (Note F) | 48,474,000 | 43,933,000 |
| Appropriation of indirect expense allowance for use of facilities | (1,285,000) | (1,209,000) |
| Auxiliary activities | 7,494,000 | 7,162,000 |
| Endowment investment income (Note A): | | |
| Total income received from investments | 16,942,000 | 15,498,000 |
| Distributed to building and other invested funds | (3,251,000) | (3,814,000) |
| Distributed to endowment funds | 13,691,000 | 11,684,000 |
| Used for scholarships and fellowships | (1,738,000) | (1,686,000) |
| Added to unexpended balances and transferred to other funds | (2,351,000) | (1,563,000) |
| Used for operations | 9,602,000 | 8,435,000 |
| Gifts, investment income, and other receipts for designated purposes | 7,878,000 | 9,621,000 |
| Unrestricted funds used to meet operating expenses | 1,593,000 | 4,907,000 |
| | $235,508,000 | $213,893,000 |

The accompanying notes are an integral part of the financial statements.

## Balance Sheets June 30, 1972 and 1971

Schedule B
*Assets*

| CURRENT FUND ASSETS | 1972 | 1971 |
|---|---|---|
| Cash: | | |
| General purposes | $ 1,843,000 | $ 1,723,000 |
| Restricted, principally to research activities | 5,476,000 | 4,482,000 |
| Accounts receivable: | | |
| U.S. Government | 4,464,000 | 3,798,000 |
| Other | 4,856,000 | 4,660,000 |
| Contracts in progress, principally U.S. Government | 24,665,000 | 18,955,000 |
| Deferred charges, inventories, and other assets | 10,129,000 | 14,019,000 |
| Due to invested funds | (3,501,000) | (6,556,000) |
| | $ 47,932,000 | $ 41,081,000 |
| INVESTMENTS (Note A) | | |
| General investments, at cost: | | |
| Fixed income | $145,997,000 | $144,931,000 |
| Equities | 92,611,000 | 87,287,000 |
| Real estate (including $16,158,000 – 1972 and $16,197,000 – 1971 for present or future Institute use) | 44,276,000 | 42,830,000 |
| | $282,884,000 | $275,048,000 |
| Investments of separately invested funds, at cost | 29,404,000 | 28,239,000 |
| Students' notes receivable | 14,194,000 | 12,889,000 |
| Total investments | $326,482,000 | $316,176,000 |
| Cash held for investment | 509,000 | 34,000 |
| Receivables arising from investment transactions | 217,000 | 1,835,000 |
| Due from current funds | 3,501,000 | 6,556,000 |
| | $330,709,000 | $324,601,000 |
| EDUCATIONAL PLANT (Note B) | | |
| Land, buildings, and equipment, at cost | $142,577,000 | $139,482,000 |
| Construction in progress | 14,911,000 | 3,471,000 |
| Temporary investments and cash | 163,000 | 167,000 |
| | $157,651,000 | $143,120,000 |
| | $536,292,000 | $508,802,000 |

The accompanying notes are an integral part of the financial statements.

Schedule B (Continued)
*Liabilities and Funds*

| CURRENT FUNDS | 1972 | 1971 |
|---|---|---|
| Accounts payable and accruals | $ 16,915,000 | $ 13,769,000 |
| Withholdings, deposits, and other credits | 4,612,000 | 4,271,000 |
| Advances by the U.S. Government for certain research contracts and grants | 22,600,000 | 18,649,000 |
| Unexpended grants for sponsored research from private sources | 2,395,000 | 2,147,000 |
| Gifts and other receipts available for current expenses | 7,680,000 | 6,893,000 |
| Notes payable, 3.65%, due 1973 (Note E) | 7,432,000 | ..... |
| Costs incurred and advance received for community housing project (Note E) | (7,432,000) | ..... |
| Due from educational plant funds | (6,270,000) | (4,648,000) |
| | $ 47,932,000 | $ 41,081,000 |
| **INVESTED FUNDS** | | |
| Endowment funds (Note A): | | |
| Income for general purposes | $ 74,199,000 | $ 73,479,000 |
| Income for designated purposes | 108,326,000 | 104,164,000 |
| Net realized gain from investments | 39,302,000 | 38,721,000 |
| Student loan funds (Note C) | 13,084,000 | 12,002,000 |
| Building funds | 10,715,000 | 14,851,000 |
| Other expendable funds: | | |
| General purposes | ..... | ..... |
| Designated purposes | 51,841,000 | 48,715,000 |
| Unexpended endowment income for designated purposes | 5,254,000 | 4,625,000 |
| Agency funds | 603,000 | 558,000 |
| Funds subject to life interests in income | 3,748,000 | 3,967,000 |
| Investment income for distribution to funds | 20,566,000 | 20,272,000 |
| | $327,638,000 | $321,354,000 |
| Notes payable – student loans | 1,469,000 | 1,124,000 |
| – investment real estate | 1,602,000 | 2,123,000 |
| | $330,709,000 | $324,601,000 |
| **EDUCATIONAL PLANT FUNDS** | | |
| Mortgage bonds and notes payable (Note D) | $ 17,649,000 | $ 14,161,000 |
| Due to current funds | 6,270,000 | 4,648,000 |
| Funds used for educational plant | 133,732,000 | 124,311,000 |
| | $157,651,000 | $143,120,000 |
| | $536,292,000 | $508,802,000 |

## Statement of Funds

for the year ended June 30, 1972

Schedule C

| | Balance June 30, 1971 | Gifts and Other Receipts |
|---|---|---|
| Endowment funds (Note A): | | |
| Income for general purposes | $ 73,479,000 | $ 665,000 |
| Income for designated purposes | 104,164,000 | 2,834,000 |
| Net realized gain from investments | 38,721,000 | 764,000 |
| Student loan funds (Note C) | 12,002,000 | 1,377,000 |
| Building funds | 14,851,000 | 3,514,000 |
| Other expendable funds: | | |
| General purpose | ..... | 3,556,000 |
| Designated purposes | 48,715,000 | 4,704,000 |
| Unexpended endowment income for designated purposes | 4,625,000 | ..... |
| Agency funds | 558,000 | 68,000 |
| Funds subject to life interests in income | 3,967,000 | 474,000 |
| Investment income for distribution to funds | 20,272,000 | ..... |
| Current year's general investment income | ..... | ..... |
| Total invested funds | $321,354,000 | $ 17,956,000 |
| Gifts and other receipts available for current expenses | 6,893,000 | 13,533,000 |
| | $328,247,000 | $ 31,489,000 |

| | |
|---|---|
| Gifts and bequests received during the year added to funds | $ 18,440,000 |
| Royalties received net of related costs | 978,000 |
| Receipts from foundations and agencies for student aid | 4,280,000 |
| Net gain on sales of investments | 1,931,000 |
| Appropriations from research contract allowances | 1,383,000 |
| Government student loan support | 923,000 |
| Government construction grants | 776,000 |
| Fees, services and other receipts | 2,778,000 |
| | $ 31,489,000 |

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 expenses .....
Operating expenses recorded in direct expenses of the Division of Sponsored Research .....

The accompanying notes are an integral part of the financial statements.

Schedule C (Continued)

| Investment Income (Note A) | Transfers In-(Out) | Expenses | Other Charges | Balance June 30, 1972 |
|---|---|---|---|---|
| $ 5,630,000 | ..... | $ 5,575,000 | ..... | $ 74,199,000 |
| * | $ 1,328,000 | ..... | ..... | 108,326,000 |
| 525,000 | (708,000) | ..... | ..... | 39,302,000 |
| 17,000 | (54,000) | 258,000 | ..... | 13,084,000 |
| 639,000 | 553,000 | 133,000 | $ 8,709,000 | 10,715,000 |
| 50,000 | (2,707,000) | 899,000 | ..... | ..... |
| 2,579,000 | 869,000 | 1,702,000 | 3,324,000 | 51,841,000 |
| 7,536,000 | (1,099,000) | 4,027,000 | 1,781,000 | 5,254,000 |
| 28,000 | (11,000) | ..... | 40,000 | 603,000 |
| 169,000 | (690,000) | ..... | 172,000 | 3,748,000 |
| {(16,596,000)<br>1,014,000} | {525,000<br>15,351,000} | ..... | ..... | 20,566,000 |
| 15,351,000 | (15,351,000) | ..... | ..... | ..... |
| $16,942,000 | $(1,994,000) | $12,594,000 | $14,026,000 | $327,638,000 |
| ..... | 1,994,000 | 6,479,000 | 8,261,000 | 7,680,000 |
| $16,942,000 | ..... | $19,073,000 | $22,287,000 | $335,318,000 |

| | | |
|---|---|---|
| ..... | $ 9,602,000 | |
| ..... | 9,471,000 | |
| | $19,073,000 | |
| ..... | | $ 8,162,000 |
| ..... | | 9,151,000 |
| ..... | | 2,728,000 |
| ..... | | 2,246,000 |
| | | $22,287,000 |

* Investment income on endowment funds for designated purposes is included under the caption "Unexpended endowment income for designated purposes."

## Summary of Changes in Funds

for the ten years ended June 30, 1972

(In thousands of dollars)

Schedule D

| | 1972 | 1971 | 1970 |
|---|---|---|---|
| Fund balances at beginning of year | $328,247 | $302,901 | $290,598 |
| Sources of funds: | | | |
| Gifts and bequests | $ 18,440 | $ 35,591 | $ 15,878 |
| Investment income (Note A) | 16,942 | 15,498 | 15,523 |
| Net gain on sales or exchanges of investments | 1,931 | 7,598 | 6,768 |
| Royalties received net of related costs | 978 | 1,058 | 963 |
| Receipts from foundations and agencies for student aid | 4,280 | 4,787 | 4,441 |
| Appropriations from research contract allowances | 1,383 | 1,209 | 1,698 |
| Government construction grants | 776 | ..... | 92 |
| Government grant for student loans | 923 | 874 | 556 |
| Fees, services, and other receipts | 2,778 | 2,781 | 3,141 |
| | $ 48,431 | $ 69,396 | $ 49,060 |
| Use of funds: | | | |
| Used to meet expenses of current operation: | | | |
| Endowment investment income (Note A) | $ 9,602 | $ 8,435 | $ 7,354 |
| Gifts, investment income, and other receipts | 9,471 | 14,529 | 13,704 |
| Scholarship and fellowship awards for tuition and stipends | 8,162 | 7,999 | 7,533 |
| Additions to educational plant | 9,151 | 6,513 | 4,283 |
| Operating expenses recorded in direct expenses of the Division of Sponsored Research | 2,246 | 2,869 | 2,627 |
| Other charges to funds not related to current operation | 2,728 | 3,705 | 1,256 |
| | 41,360 | 44,050 | 36,757 |
| Net increase in funds | 7,071 | 25,346 | 12,303 |
| Fund balances at end of year | 335,318 | 328,247 | 302,901 |
| Less gifts and other receipts available for current expenses | 7,680 | 6,893 | 8,900 |
| Total invested funds | $327,638 | $321,354 | $294,001 |

The accompanying notes are an integral part of the financial statements.

Schedule D (Continued)

| 1969 | 1968 | 1967 | 1966 | 1965 | 1964 | 1963 |
|---|---|---|---|---|---|---|
| $259,882 | $239,902 | $229,119 | $190,722 | $173,910 | $150,008 | $134,875 |
| $ 25,069 | $ 22,147 | $ 16,019 | $ 39,186 | $ 21,690 | $ 20,221 | $ 17,479 |
| 14,579 | 13,502 | 12,788 | 10,455 | 9,482 | 8,039 | 7,245 |
| 14,068 | 9,221 | 3,008 | 5,153 | 3,155 | 4,328 | 3,874 |
| 1,772 | 698 | 709 | 519 | 1,234 | 13,134 | 310 |
| 4,624 | 4,698 | 4,881 | 4,821 | 4,207 | 1,843 | 1,230 |
| 1,405 | 1,627 | 1,921 | 1,571 | 1,471 | 1,236 | 1,120 |
| 2,188 | 2,028 | 1,793 | 1,294 | 3,148 | 755 | 750 |
| 639 | 699 | 677 | 850 | 686 | ..... | ..... |
| 2,921 | 3,007 | 1,276 | 1,078 | 875 | 1,197 | 1,362 |
| $ 67,265 | $ 57,627 | $ 43,072 | $ 64,927 | $ 45,948 | $ 50,753 | $ 33,370 |
| $ 7,351 | $ 6,865 | $ 4,859 | $ 4,490 | $ 2,810 | $ 2,667 | $ 2,014 |
| 10,344 | 11,113 | 9,970 | 8,242 | 6,833 | 6,223 | 6,592 |
| 7,279 | 7,566 | 6,879 | 5,703 | 4,673 | 2,635 | 2,143 |
| 7,067 | 10,076 | 8,509 | 6,815 | 13,096 | 10,725 | 5,768 |
| 1,957 | 1,062 | 1,241 | 72 | 261 | 144 | 503 |
| 2,551 | 965 | 831 | 1,208 | 1,463 | 4,457 | 1,217 |
| 36,549 | 37,647 | 32,289 | 26,530 | 29,136 | 26,851 | 18,237 |
| 30,716 | 19,980 | 10,783 | 38,397 | 16,812 | 23,902 | 15,133 |
| 290,598 | 259,882 | 239,902 | 229,119 | 190,722 | 173,910 | 150,008 |
| 7,775 | 6,441 | 6,939 | 7,064 | 5,880 | 4,658 | 3,411 |
| $282,823 | $253,441 | $232,963 | $222,055 | $184,842 | $169,252 | $146,597 |

## Notes to Financial Statements

A-INVESTMENTS
Total market value of investments approximated $439,596,000 and $395,428,000 at June 30, 1972 and 1971. Such amounts include market values of certain real estate which were determined by professional appraisers. See the schedule of investments for further details.

B-EDUCATIONAL PLANT
Educational plant, representing land, buildings, and equipment, is shown at cost. No provision for depreciation has been charged to operations.

C-STUDENT LOAN FUNDS
National Direct Student Loan Funds of $6,077,000 and $4,967,000 at June 30, 1972 and 1971, respectively, are ultimately refundable to the United States Government.

D-MORTGAGE BONDS AND NOTES PAYABLE
Mortgage bonds and notes payable consist of the following at June 30, 1972 and 1971:

| | 1972 | 1971 |
|---|---|---|
| M.I.T. Construction and Consolidation Bonds of 1968: | | |
| Series A, 3 1/2%, due 1972-2003 | $ 5,283,000 | $ 5,378,000 |
| Series B, 3 3/4%, due 1972-2015 | 3,851,000 | 3,886,000 |
| Series C, 3%, due 1972-2018 | 1,655,000 | 1,670,000 |
| | 10,789,000 | 10,934,000 |
| Dining facilities bonds, 3 1/8%, due 1972-1999 | 335,000 | 342,000 |
| Mortgage notes payable, 5 1/4%, due 1972-1978 | 663,000 | 747,000 |
| Mortgage notes payable, 5 1/4%, due 1972-1981 | 678,000 | 753,000 |
| Residential facility lease purchase obligation (Note E) | 5,184,000 | 1,385,000 |
| Total related to educational plant | $17,649,000* | $14,161,000 |
| Notes payable 6%, due 1972-1976 | 372,000 | 465,000 |
| Notes payable 6%, due 1972-1978 | 985,000 | 1,364,000 |
| Note payable, non-interest bearing, due 1972-1977 | 245,000 | 294,000 |
| Total related to investment real estate | $ 1,602,000 | $ 2,123,000 |
| Notes payable to bank, 4 3/4 - 5 1/2%, due 1972-1973 for student loans | $ 1,469,000 | $ 1,124,000 |

* The Institute has pledged securities with a market value of $3,042,000 at June 30, 1972 to comply with the terms of bond indentures.

E-COMMITMENTS

1. During 1970, the Massachusetts Health and Educational Facilities Authority agreed to construct a residence facility and provide additions to heating and chilled water plant for lease to the Institute with title passing to the Institute upon expiration of the leases. Construction costs of $10,500,000 were met by an issue of Authority Bonds with the Institute paying the additional costs required to complete the residence facility.

   Construction costs of the residence facility incurred to date, recorded as educational plant, amount to $5,553,000, of which $5,184,000 represents the associated liability to the Authority. Annual payments under the 30-year lease purchase agreement approximate $350,000.

   Annual rentals for the utility facilities, which are being leased for their estimated 25-year useful lives, approximate $400,000 and are being charged to plant operations as incurred.

2. On June 30, 1971, the Cambridge Housing Authority, supported by the U.S. Department of Housing and Urban Development, contracted to purchase from the Institute three low-income housing facilities for the elderly for $17,092,000. During 1972 the Institute obtained

construction financing for the project from the Massachusetts Housing Finance Agency in the amount of $15,600,000. Interest is payable monthly at the annual rate of 3.65 percent and principal is due October, 1973. The remaining costs will be paid directly from the proceeds of the sale. Total costs, including interest charges, are not expected to be in excess of the selling price. The amount of $1,482,000 which the Institute had advanced and included in deferred charges at June 30, 1971, to acquire the sites was covered by the MHFA financing at June 30, 1972.

F-DRAPER LABORATORY

As a step toward the ultimate divestment of Draper Laboratory, the Institute has entered into an agreement with all Federal government agencies sponsoring research activity at the Institute relative to certain procedures in the methods of reimbursement for indirect costs. This may create an additional demand on general and unrestricted resources in the fiscal year 1974 and thereafter.

During fiscal years 1972 and 1971, Draper Laboratory total revenues were $48,474,000 and $43,933,000, respectively, including reimbursement for part of the Institute's indirect expenses.

G-RETIREMENT FUNDS

The Institute's retirement plans, which cover substantially all employees, are under the supervision of trustees. Plan assets are not included in the Institute's financial statements. Current service costs of the plans are funded as incurred; prior service costs are expected to be fully funded in approximately 14 years. Pension expense charged to operations was $8,516,000 and $7,293,000 in fiscal 1972 and 1971, respectively.

## Auditor's Report

TO THE AUDITING COMMITTEE OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY:

We have examined the following financial statements of Massachusetts Institute of Technology:

Schedule A — Sources of Revenues and Funds Used to Meet Expenses of Current Operations for the years ended June 30, 1972 and 1971.
Schedule B — Balance Sheets as of June 30, 1972 and 1971.
Schedule C — Statement of Funds for the year ended June 30, 1972.
Schedule D — Summary of Changes in Funds for the ten years ended June 30, 1972.

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 previously performed similar examinations of the financial statements for each of the nine years ended June 30, 1971.

In our opinion, said statements present fairly the financial position of Massachusetts Institute of Technology at June 30, 1972 and 1971, and the results of its operations for the years then ended and changes in funds for the ten years ended June 30, 1972, in conformity with generally accepted accounting principles applied on a consistent basis.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts, September 15, 1972

## 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, 1972, and their report is submitted herewith.

Respectfully,
Donald F. Carpenter
David A. Shepard
Frank R. Milliken, Chairman

# Vice President, Operations

Continuing and intensified efforts were undertaken this year to control and reduce service expenditures without seriously damaging the fabric of effective support to the Institute and its mission. Concrete results have been achieved from these efforts. Organizational streamlining, energy conservation efforts, and cost control measures have combined to reduce expenditures in real dollars in the face of inflationary pressures and modest growth. The success of these measures is due in large part to the skill and energy of the present strong, young, and vigorous leadership of the several operational service departments.

## Physical Plant

### Operations

Substantial restructuring of the Physical Plant organization has continued, and the close of the year finds the department with a more closely integrated functional organization. This group is made up of six major divisions: power and utilities, grounds, building maintenance and repair, building services, telecommunications, and engineering and construction. These groups are supported by an administrative staff composed of the combined Director's and Superintendent's offices. This reorganization has improved the capability of the several groups to react promptly and effectively to problems, has allowed for a closer alignment and coordination of goals and objectives, and is producing a very favorable effect on expense control and cost effectiveness.

The computer oriented job-cost/work order control system continues to take a primary focus in the operations of the plant. Work orders for preventive maintenance tasks in the mechanical services area are now machine produced on a routine basis. The cross-indexed files for key data and key control are now computerized and fully operational. This has enabled the undertaking of an extensive program for purging, updating, and correcting the key lists sent to departmental administrators.

In recognition of continuing escalation in the costs of purchased energy and utilities, an Energy Conservation Program was initiated early in the year. Substantial savings have accrued as a result of this cooperative effort with the various departments to conserve heat and power. As a result, steam consumption over the year was reduced by approximately 50 million pounds or 6 percent of the total amount consumed in the previous year. Likewise, electrical consumption has been reduced significantly; after many years of continuous yearly growth, electrical consumption for the year decreased by 2 percent. The overall savings from the program have been most encouraging, and the effort will be continued and expanded wherever possible.

On August 12, 1972, the electro-mechanical telephone switch, which has provided telephone service to M. I. T. since 1942, will be replaced by CENTREX (central exchange), an electronic switching system. Preparation for the conversion, including training sessions to acquaint more than 300 Institute representatives with the installation, has been in process for more than five years in cooperation with the New England Telephone Company. The number of telephones involved, including lines used for data communication services,

will be 8, 350. The changeover also will involve the creation of a separate telephone system for the Draper Laboratory. A primary feature of the system is that outside callers will be able to reach M.I.T. extensions directly rather than through a switchboard; as a result, faster, more efficient service will be provided.

This year marks the retirement of 38 people from the organization. Among these were Richard E. Collins, Technical Assistant, with 25 years of service, and John L. Ayer, Special Assistant, Grounds, with 38 years of service.

### Construction

The Burton-Conner undergraduate dormitory renovation was completed in the fall of 1971. The dormitory renovation took 14 months and involved a complete renewal of the building except for the masonry shell and the wooden floors.

Construction of Westgate II, a high-rise residential facility on the west end of campus, continued during the year with occupancy scheduled for the fall of 1972. Westgate II will house 401 single graduate students in one-, three-, and four-bedroom apartments.

The J. B. Carr Indoor Tennis Center on Briggs Field was completed in the fall of 1971. The Tennis Center is housed in an inflatable structure that accommodates four tennis courts.

Construction continued during the year on the Electrical Engineering and Communications Research Building. The structural frame was completed in May, 1972, and the date for total completion is now forecast as June, 1973.

The major additions to the Central Utilities Plant are nearing completion. This will be the culmination of a three-year program to add both steam boiler and chilled water capacity, as well as to extend the campus steam distribution system, to the new West Campus housing facilities.

New projects in the preliminary design stage or under consideration include a Chemical Engineering Building, to be located to the east of the Whitaker Building; renovation of Ashdown House; renovation of a section of the Ford Building for health-related research; and additional student housing on the West Campus.

## Housing and Food Services

A number of changes in the management personnel of Housing and Food Services occurred during the year. In March, Howard F. Miller, Director of this department, joined the Physical Plant staff as Assistant to the Director. At this time, Harmon E. Brammer, Administrative Officer in the Department of Electrical Engineering, was appointed as his replacement. In July, Joseph F. Lynch returned to this department as Housing Area Manager, Burton-Conner and MacGregor House. During his two-year absence he was attached to the Opportunity Development Office's training program.

Arthur Schott, a member of the maintenance staff at Baker House, was honored as co-recipient of the James N. Murphy Award at the annual awards convocation. This award is presented annually to an M.I.T. employee whose spirit and loyalty exemplify the service of Mr. Murphy, especially with regard to students.

In September of this year Burton-Conner was once again occupied by the students after a year's absence during a major renovation program. This facility now houses 344 undergraduates in modern suite-style accommodations. This new style of residential living is the second facility of its type now in service on campus.

## Campus Patrol

The Campus Patrol provides for the safety and welfare of the M. I. T. community 24 hours a day, seven days a week, furnishing many services for which it is uniquely qualified by reason of its training, as well as its 24-hour availability. Such services include response to medical emergencies, accidents, and fires; investigation of larcenies, missing persons, suspicious persons, and extraordinary human behavior; and supervision of motor vehicle registration, traffic control, and parking.

Unfortunately, the Institute finds itself in a situation similar to other centers of population where crime rates have increased dramatically in recent years. In 1968, the total number of complaints received by the Campus Patrol was 806. Just three years later, this number had risen to 1, 561. Similarly, during the same period, time spent by Campus Patrol officers presenting cases in court rose from 123 hours to 1, 078 hours, stolen cars from 99 to 169, and stolen bicycles from 93 to 246.

An even more serious matter for concern, however, is that criminal acts committed by outsiders on the M. I. T. campus are increasing at a significant rate. For example, assaults on campus have jumped from 10 to 22 in just one year. During the past year, several dangerous criminals have been apprehended on campus and prosecuted in the courts. These circumstances have prompted the Campus Patrol to initiate an escort service for those people who wish it and for those who are leaving their offices, laboratories, or classrooms beyond the normal working hours.

## Safety Office

The record of accidents at the Institute showed a gratifying decrease this year over last. The frequency rate in terms of the number of lost-time accidents declined by approximately 17 percent and the severity rate by approximately 32 percent.

The upgrading of the fire alarm system and augmentation of automatic sprinkler protection continued during the year. Although an increase in the number of fires is noted, most of them were of the small, nuisance type, and major problems were averted by automatic sprinklers.

The impact of the Williams-Steiger Occupational Safety and Health Act over the past ten months has been of major significance. While the Safety Office has anticipated many of the matters covered by this legislation, considerable effort on the part of all departments of the Institute is required if it is to keep up with the requirements of the law as they continue to unfold. It is anticipated that the activities of the Safety Office for the coming year will be involved heavily in the implementation of and compliance with the standards of this act.

## Graphic Arts Service

Although the situation seems to be stabilizing, Graphic Arts continues to be affected by the decrease in available budgets throughout the Institute. The gross dollar volume of the work of this service is approximately the same as last year, which was down 9 percent from 1969-70. There is a continuing desire on the part of the M. I. T. community for lower costs through the use of lower quality reproduction and printing services. Quick copy type services continue to increase at the expense of other methods. In order to meet this demand most effectively, a new multilith system has been purchased.

A new field for Graphic Arts Service this year is typesetting. Equipment has been procured which enables the setting of all type for important M. I. T. publications. This is proceeding on a trial basis, but it is believed that beneficial results for the Institute will occur and, if this is so, Graphic Arts Service may expand further in this field.

In order to provide the Audio-Visual Service with needed support services, the Graphic Arts Service has reassumed administrative responsibility for this group.

PHILIP A. STODDARD

# Vice President

## Academic Calendar

The academic year 1971-72 saw the second year of our experimentation with a new calendar providing for an Independent Activities Period, "the I.A.P.," in January. The faculty adopted this new calendar in March, 1970, on a three-year trial basis. A student-faculty-administrative committee chaired by Professor Kent Hansen provided policy guidance and conducted an extensive evaluation through questionnaires, surveys, and discussions. Joel Orlen, assistant to the Provost, served as I.A.P. Planning Officer and provided administrative coordination among departments and laboratories, student groups and administrative offices.

Following our experience with the first I.A.P. in January, 1971, we were able this year to provide earlier and better planning. Nevertheless, we were very conscious of the real possibility that over-organization might detract significantly from the independence and flexibility which had been so much appreciated during the first year of the trial. The unique design of the 1972 I.A.P. Guide and other printed material which Mr. Orlen and his associates evolved seemed to be one of the key factors which, taken together, apparently preserved the desired character.

The evaluation of both students and staff as reported to Professor Hansen's policy committee and generally through the campus media was, if anything, even more favorable than the very favorable evaluation of the 1971 I.A.P. Consequently, the academic calendar which provides for this independent period in January will be continued for the final year of the three-year experiment, 1972-73.

At the time this experimental calendar was adopted, both the Committee on Educational Policy and the ad hoc calendar committee under Professor James Munkres spoke to the longer-range need for continuing study and evaluation of other calendar reforms. Over this past year there has emerged a greater interest in exploring in considerable depth the potential advantages which might occur under a calendar which provided for better articulation and integration of the three-month summer period with the traditional nine-month academic year. Although there are obvious considerations of plant utilization and efficiency, these have been secondary to the educational considerations. Our preliminary discussions indicate that there may be considerable educational benefits to be gained through careful development of a "year-round" calendar.

The Committee on Educational Policy has established a subcommittee under the chairmanship of Professor Wilbur Davenport to participate in these studies. Vice President Wadleigh has been asked to coordinate the efforts of this group with that of other staff to examine the possibilities which might be afforded by year-round operation and to formulate recommendations for calendar changes if such changes appear to be productive. In preparation for intensive work this coming fall, considerable time will be spent this summer seeking the views of many individual members of the faculty on the impact of changes in the academic calendar on educational and professional objectives.

## Housing

We had hoped to find ways in which to initiate significant new residential construction near the campus, particularly in the area northwest of the athletic field--the "Northwest Area-Simplex" site. However, the high cost of land, of new construction, and of borrowed capital combine to make for rental levels which we believe to be too high to attract significant numbers of the M.I.T. community. Thus, while we continue to explore alternate approaches, we have to this date been unable to identify one which is sufficiently promising in view of the large risks involved.

The inflationary trends in local residential real estate have also had a profound effect on the ability of our Northgate Community Corporation to operate effectively as an off-campus housing resource primarily for members of the M.I.T. community. Northgate's taxes, fuel costs, and other operating costs have increased over the past few years at a rate much higher than the rate of increase of the income of most of its tenants. These financial problems seem to have been further exacerbated by the political/legal confusions which have accompanied the imposition of rent control in Cambridge and Somerville.

Although Northgate did succeed in having those of its dwelling units for which M.I.T. affiliations were required for occupancy excepted or exempted from rent control under two separate rent control administrations in Cambridge, some of Northgate's tenants are attempting further court tests of these actions. Other tenants are simply refusing to pay the rent increases which Northgate states are both legally valid and necessary to reduce its operational deficits. Thus, the Institute, through Northgate, has found itself in the position of a landlord engaged in divisive frays with tenants, who are in turn, for the most part, employees or students of the Institute. At this writing, it is not at all clear that it will be possible for Northgate to return to its original position as a desirable housing resource from its present position of severe financial and tenant relations problems. Given the financial and political climate in which this corporation must operate off-campus, certainly it is not the time for Northgate to attempt to initiate new construction.

On campus, Westgate II, our new single graduate student residence, will become available shortly after the opening of the fall term of 1972. Coincidentally with its opening, we will begin a long-needed renovation of Ashdown House, a 70-year-old building which has been a graduate student residence since its acquisition by the Institute in 1937. This renovation will be undertaken in two phases over the next two academic years so that the house will provide only about one-half the normal number of student accommodations over this period. When Ashdown is completed, the Institute will have in Ashdown House and Westgate II accommodations for about 800 single graduate students -- about one-half of our total population of single graduate students.

We are currently engaged in planning the next phase of on-campus student housing, a new construction project which would provide from 50 to 150 dwelling units accommodating from 50 to 300 students, depending upon the breakdown in occupancy between single and married students. The most attractive site on which to locate such a project appears to be at the west end of the campus -- on the area adjacent to Westgate I and Westgate II.

In the report of the Dean for Student Affairs more information on the on-campus residential program and on new developments in the fraternities is presented.

## Pilot Program for Prepaid Comprehensive Health Care

In his report on the Medical Department which follows, Dr. Seeler comments on his staff's planning to offer prepaid comprehensive health care in a Pilot Program for 1,000 M.I.T. employees and their dependents. I am pleased to report that shortly after Dr. Seeler wrote his comments, the President, Chancellor, and other senior officers gave their approval for

the Medical Department to undertake this Pilot Program.

We anticipate that the final preparations which will move us from the present planning stage to actual implementation -- including the marketing of the program within the M.I.T. community -- will consume at least the fall term of 1972. Hopefully, the medical staff will be able to begin the actual delivery of health care to those who enroll in January, 1973, or shortly thereafter.

We will also now begin to undertake the planning for a possible next phase -- a full-scale health maintenance organization for all regular students and their dependents and, on an optional basis, for all employees and their dependents.

We are very conscious of the need in such planning to coordinate our efforts with those of similar developments in the greater Boston area. Thus, while we now anticipate that the 1,000-family program will be a success and that we will build upon it to mount a full-scale effort, we recognize that rapid developments in health care may result in our identifying a more desirable solution prior to our undertaking the staff augmentation and building construction required for a full-scale M.I.T. based health maintenance organization.

### Personnel

After eleven years of close team effort with me, Alice Seelinger is leaving my office to take a new and important staff role in the office of the Dean for Student Affairs. Miss Seelinger began these eleven years as a secretary in the Dean's office, but in recognition of her great contributions to all of the programs and problems of students and staff, she was soon made a member of the administrative staff. I express my most sincere thanks for her assistance far beyond the call of duty, and I wish her well as she now returns to student affairs.

KENNETH R. WADLEIGH

## Medical Department

There was a modest increase in utilization of the Medical Department. The number of visits to the clinics rose from 71,613 to 73,371, an increase of 2.2 percent. The total number of visits to the Medical Department, including the Lincoln Laboratory medical unit and emergency visits to the M.I.T. Infirmary, rose from 84,869 to 88,009, an increase of 3.7 percent. There was a 21 percent increase in visits to the emergency clinic, for which we have no explanation.

As noted in last year's report, the lack of adequate space for our nurse practitioners is a critical problem. We introduced the nurse practitioner concept 12 years ago and it is now generally recognized that an effective nurse practitioner component is essential for a rational health delivery system. We have increased the number of nurse practitioners to meet the increasing demands for medical care, but we do not have satisfactory facilities for them. Unfortunately, they have to share consulting rooms, with the resulting serious handicap of a lack of privacy.

The inadequate space for medical records is another critical problem. The demand for medical records is now so great that our filing machines are no longer satisfactory. At best they are quite slow and the number of breakdowns has increased to the point where it seriously interferes with medical care, as a physician or nurse practitioner should have the record available when seeing a patient. Our Consultant Medical Records Librarian believes that the only solution is open shelf filing, which requires more space than we have at present.

Earl M. Harvey, M.I.T. Staff Architect, has studied these problems for us and has evaluated

the possibility of a mezzanine on our first floor. The mezzanine concept, though attractive, has had to be rejected because it would be impossible to continue effective operation of the medical services during its construction. The most economical and least disruptive solution is to extend the Medical Department space to an adjoining classroom, which would be used for the medical record files, and remodel several of our present first floor consulting rooms to provide small but adequate private offices for our nurse practitioners. This planning assumes that a new facility will be available for the Medical Department within five years and that the present space will be used by the Institute for other purposes.

As has been mentioned in previous reports, the Medical Department has been studying the feasibility of offering a comprehensive prepaid medical care plan to the dependents of the M.I.T. faculty, staff, and employees. With the help of Daniel F. Creasey of the Analytical Studies Group, such a plan has been developed and been subjected to fiscal analysis. On the basis of this evaluation, the Medical Department believes that a prepaid program will not only meet the urgent need of the M.I.T. community for high-quality medical care, but will help control the escalating costs of such care. The program is now being considered by the M.I.T. administration. The Medical Department hopes that it will be given permission soon to enroll 1,000 M.I.T. families whom we can take care of in our present facilities and start detailed planning for a building large enough to provide care for the entire M.I.T. community.

## Personnel

Two physicians have joined our full-time staff during the year. Dr. Franklin D. Aldrich, an internist with extensive experience in toxicology, has become the physician in charge of the Environmental Medical Service. Dr. Edward C. Dyer, a pediatrician, has taken charge of our pediatric clinic and also, because of his interest in medical problems of the young adult, is devoting a large portion of his time to the medical care of students and their spouses.

*Appointments, 1971-72*

Appointments during the year were the following: Franklin D. Aldrich, M.D., Physician in Charge of the Environmental Medical Service; Steven Aron, M.D., Associate Ophthalmologist; Theodore C. Barton, M.D., Gynecologist; George Blackburn, M.D., Assistant Surgeon; Paul L. Dratch, M.D., Radiologist; Edward C. Dyer, M.D., Physician; Stanley C. Foster, M.D., Radiologist; Norma B. Loomis, A.S., Supervisor, Insurance and Billing; Donald McKay, M.D., Assistant Surgeon; Sanford M. Reder, M.D., Assistant Physician; Lloyd V. Sutfin, D.M.D., Dentist; and Janet M. Wright, B.A., Administrative Assistant.

*Resignations, 1971-72*

Resignations during the year included: Phin Cohen, M.D., Assistant Physician; William L. Curwen, M.D., Associate Dermatologist; Alan S. Diamond, M.D., Assistant Surgeon; Albert H. Feingold, M.D., Psychiatrist; Arnold W. Fieber, Medical Records Consultant; Lawrence T. Geoghegan, M.D., Assistant Surgeon; Burton J. Gove, D.M.D., Dentist; Winslow W.C. Green, M.D., Assistant Surgeon; Gilman W. Haven, D.D.S., Dentist; Irving Hurwitz, Ph.D., Psychologist; Lawrence J. Malone, M.D., Gynecologist; Donald McKay, M.D., Assistant Surgeon; Ruth A.J. Runyon, M.D., Assistant Physician; Gustav Schonfeld, M.D., Assistant Physician; Helen D. Wallach, M.D., Associate Psychiatrist; and Robert L. Waldron, II, M.D., Radiologist.

## Clinics

The number of clinic visits and the distribution among the various groups of the M.I.T. Community are shown in Table I. There was a small increase in the number of visits to the Medical Clinic, but there was a slight decrease in the number of visits to the Surgical Clinic. The utilization of the various specialty clinics increased by about 5 percent.

The Pediatric Clinic begun last year has been continued. It is staffed by a part-time pediatric nurse practitioner who is under the supervision of a pediatrician. It is operated on a fee-for-service basis. There were 834 visits, and 296 individual children were seen. This service is available to any child in the M.I.T. community.

There were 499 athletic injuries treated during the year. As usual, "touch" football led the list with 129 injuries; hockey with 89, basketball with 83, and soccer with 61 were also heavy contributors to the injury list.

## Dental Service

There were 6,392 visits to the Dental Service during the year. A fully equipped dental room has been added to the facility and an additional dental assistant has joined the supporting staff. Dr. Lloyd Sutfin, a periodontist, has become a member of the dental staff on a part-time basis. Except for emergencies, dental care is limited to students and their spouses, but the demand for dental care from this group is so great that many students must be referred to the few private dentists in the community who are still willing to accept transient patients.

## Health Surveys

Complete medical examinations for 1,067 faculty and senior D.S.R. staff members were performed, an increase of 6 percent over last year. These examinations require at least an hour of internists' time and are offered without charge, except for some of the associated laboratory work. While the Medical Department believes that periodic health surveys are of value and should be encouraged, they are very costly and consideration is being given to methods that will reduce the physician time required without reducing the quality of the survey.

## Employee Health Program

The total number of examinations performed was 2,402, an increase of 4.3 percent. While the number of pre-employment examinations dropped 12 percent, there was an increased demand by our employees for health surveys, which led to the increase in load.

Only one job applicant was found to have a disqualifying health problem. Twenty-four other applicants had significant health problems but were offered jobs.

Including retired employees, 16 deaths were recorded during the year. As usual, heart disease and cancer accounted for the majority of deaths.

## Psychiatric Service

The utilization statistics are given in Table II. The number of individuals seen and the total number of visits were about the same as last year. The use of the Infirmary for psychiatric problems showed a striking increase as this was the first full year in which the new Infirmary was available. The opportunity to hospitalize emotionally disturbed students in a relatively non-threatening environment has been of great value. In many instances, the students were able to attend classes from the Infirmary. Only seven patients required admission to a psychiatric hospital.

There was a sharp reduction in acute drug intoxication ("bad trips") and as a corollary the Service believes that there was much less use of LSD and mescaline than in the past. There seems to have been very little use of narcotics on campus. Many students use marijuana socially and the use of alcohol seems to be increasing.

Major changes in the mental health laws of the Commonwealth occurred last year which ensure greater protection of the liberty of patients. These laws, however, make hospitalization of the mentally ill a very complex procedure, demanding very much more physician time for the arrangements.

As in the past, the members of the Psychiatric Service have spent a great deal of time working with various groups at the Institute to help with social problems. Consultation with the Office of the Dean for Student Affairs and the Foreign Student Office continues to be a very important part of the Service activity.

Dr. Carola Eisenberg's work with the Women's Forum and many student groups has been so outstanding that she has been appointed Dean for Student Affairs. The Medical Department views this change in Dr. Eisenberg's responsibilities with pride in her accomplishments, but also with regret at losing her from the Department.

## Social Work Service

There were 1,302 visits, an increase of 51 percent over the previous year. This striking extension in service occurred because this was the first full year that we have had two full-time social workers to meet the great demand for help in this area. As in the past, individuals from all the various groups in the M.I.T. community sought help. Employees were the largest client group.

In addition to direct service to clients, the social workers have given a great deal of time to many broad problems of the Institute, such as the Day Care Program, the retraining programs, the requirements of the blind and other handicapped students, and the special needs of minority groups.

## Infirmary

This was our first full year of operation of the M.I.T. Infirmary in the building which formerly housed the Sancta Maria Hospital. While very conscious of the inefficiency inherent in separating inpatient from outpatient facilities, we have been delighted to have a facility which is well equipped, pleasingly decorated, and relatively spacious. The utilization statistics are given in Table III. The striking difference from the previous year was the increase in non-student use of the Infirmary. This resulted from a Medical Department decision to use the Infirmary as much as possible for non-student patients, since space in excess of our student needs is now available. It is now our policy to use the Infirmary for all patients whose illness is not so critical that they should be in the intensive care facility of a general hospital. No major surgery is performed in the Infirmary, but patients who have had major surgery in a general hospital are being returned for postoperative care.

A total of 421 minor operations were performed during the year. Most operations were for the suture of lacerations and excision of benign skin lesions. In addition, however, there were 13 vasectomies, 8 excisions of malignant lesions, 6 cystoscopies, and 1 bronchoscopy.

As usual, non-specific viral illness led the list of discharge diagnoses, with gastroenteritis being the second most common diagnosis. Infectious mononucleosis accounted for 5 percent of the admissions.

As mentioned in last year's report, we have had difficulty with what we had hoped would be an ideal food preparation system, namely the use of microwave ovens to warm precooked frozen food. We have abandoned this method and are now serving hot food brought over from one of the Institute kitchens.

## Clinical Laboratory, Electrocardiography, X-ray

The Commonwealth Clinical Laboratory continues to handle laboratory work except for blood lipid chemistry which is done by the laboratory of the M.I.T. Clinical Research Center. The total number of tests performed was 35,934, which is about the same as last year.

The number of electrocardiograms taken (1,551) was about 5 percent greater than last year, while the number of x-rays (9,825) was about the same as last year.

## Sanitation

Routine bacteriological monitoring of the M.I.T. food services and the swimming pool continues to be handled by the Massachusetts Dairy Laboratories. Fred E. Smith, our Consultant Sanitary Engineer, reviews the bacteriological reports and inspects the facilities regularly. There were no outbreaks of food-borne infection during the year. There was a period last summer in which coliform bacteria were found in swimming pool water. Thorough examination of the pool equipment showed it to be in good order. No cause for the contamination was found and there have been no more abnormal bacteriological tests.

## Student Health Insurance

All regular M.I.T. students are required to pay a Health Service Fee which covers all diagnostic and therapeutic care given by the Medical Department, as well as hospitalization in the M.I.T. Infirmary. A commercial hospital and accident insurance is offered, but is optional. Although we urge students to carry adequate hospital and accident insurance, each year there are a few students who must be hospitalized who either have no insurance coverage or, particularly in the case of foreign students, coverage that is grossly inadequate. Some hospitals now will not take our students unless M.I.T. guarantees payment of the hospital bill. The Medical Department continues to recommend that all students be required to have adequate hospital and accident coverage.

## Environmental Medical Service

This was the first year of operation of the Service under the direction of Dr. Franklin D. Aldrich. The basic responsibility of the Service, which is to protect the M.I.T. community and its neighbors from exposure to radiation and toxic hazards, remains unchanged and continues to be handled superbly by Richard I. Chamberlin, Industrial Hygiene Officer, and Samuel Levin, Radiation Protection Officer, and their associates. This was a transitional year for the research activities of the Service, as Dr. Aldrich had to become acquainted with the M.I.T. community and also study and evaluate the ongoing complex and sophisticated programs of the Service itself. It is Dr. Aldrich's intention to foster collaborative work with various M.I.T. departments in areas of environmental concern. This program was begun during the year with work in association with Professor Damon E. Cummings on studies of the human body burden of heavy metals, in a coastal area of Maine where open pit mining has been done for many years. A project in cooperation with Professor Emily L. Wick to study environmental nitrosamines and their possible relationship to human disease is being considered.

### *Industrial Hygiene Office*

The basic services, including the evaluation of potentially hazardous environments, the respiratory protection program, the hearing conservation program, and the hood survey program have been continued as in the past. The increasing interest in the overall environment together with the publicity associated with the Occupational Safety and Health Act has resulted in many more requests for advice. This was especially evident in the demand for noise surveys.

Special projects of the Industrial Hygiene Laboratory included analysis of tissue samples for the Beryllium Case Registry, analysis of paint samples for lead as part of an investigation to find potentially hazardous areas, and analysis of all waste water for mercury during a survey period.

Engineering studies during the year included laboratory changes in Buildings 4 and 6, improved ventilation for animal quarters in E10, and evaluation of the exhaust systems in Building 18. Presently, plans are being developed for a separate animal facility in E20, a virus preparation room in Building 16, and a new radioactive waste storage area. Ventilation design work for the new Chemical Engineering Building is in progress.

*Radiation Protection Office*

The various phases of the Radiation Protection Program were continued essentially unchanged. The volume of radioactive waste collected and processed rose by approximately 40 percent. This increase was caused by greater use of scintillation counting, more concern about environmental pollution, and increased use of disposable laboratory supplies.

During the year, the Laboratory of Nuclear Science's 400 MeV Linear Accelerator was successfully tested at 6, 23, and 100 MeV. This facility will continue to present difficult problems in radiation protection.

*Institute Veterinarian—Animal Care Program*

During the past year, the Office of the Institute Veterinarian has, for administrative purposes, come under the aegis of the Environmental Medical Service. The newly reconstituted Institute Animal Care Committee, charged by the President with the responsibility for ensuring proper care and humane treatment of animals, and for protecting human health, has structured a centralized animal care office under the direction of the Institute Veterinarian, who serves as Executive Secretary to the Committee.

The use of animals for research and teaching at M.I.T. has increased dramatically over the past several years. During this past year, over 25,000 such animals were utilized; it is realistic to expect that the numbers will continue to increase in the future. Care of these animals, protection of the health of humans in contact with them, and the provision of consultative services to experimenters who use them comprise the triad of responsibility of the Committee and the Institute Veterinarian.

With the help of the Committee much progress was made this past year in defining the roles of the Institute Veterinarian and his office. In addition, improvements were made in the physical facilities of some of the animal laboratories. These changes were sufficient for the Institute to be granted full accreditation by the American Association for Accreditation of Laboratory Animal Care. Such accreditation is now, or soon will be, required by most fund-granting agencies, including the National Institutes of Health.

In addition to further implementation of plans to centralize all animal care functions in the Office of the Institute Veterinarian, there are other problems and challenges. The need for adequate receiving, quarantine, and isolation facilities as well as physical resources for the treatment of sick animals will increase as the number of animals increases. It may be necessary for a new central physical facility to be created for these purposes.

ALBERT O. SEELER, M.D.

TABLE I CLINIC VISITS

| | June 1, 1970-May 31, 1971 | June 1, 1971-May 31, 1972 | Percentage change |
|---|---|---|---|
| Medical | 29,274 | 29,670 | +1.4% |
| Surgical | 10,784 | 10,467 | -2.9 |
| Other | 31,555 | 33,234 | +5.3 |
| TOTAL | 71,613 | 73,371 | +2.5 |
| Faculty | 3,446 | 3,177 | -7.8% |
| Staff | 7,094 | 7,876 | +10.1 |
| Students | 37,720 | 39,030 | +3.5 |
| Student spouses | 5,637 | 5,283 | -6.3 |
| Employees | 13,985 | 14,699 | +5.1 |
| Other | 3,731 | 3,306 | -11.4 |
| TOTAL | 71,613 | 73,371 | +2.5 |

TABLE II PSYCHIATRIC SERVICE

June 1, 1971 - May 31, 1972

| | |
|---|---|
| Total individuals seen | 1,304 |
| Total number of visits | 4,953 |

| Analysis of caseload | Number of patients seen |
|---|---|
| Freshman | 75 |
| Sophomore | 98 |
| Junior | 122 |
| Senior | 146 |
| Special* | 12 |
| Uncertain | 36 |
| Graduates | 226 |
| Spouses | 70 |
| Faculty | 70 |
| Staff | 96 |
| Employees | 145 |
| Faculty Health Survey | 2 |
| Other | 79 |
| Alumni** | 127 |
| Total number of patients hospitalized | 7 |
| Total number of patients referred to clinic | 56 |
| Total number of patients referred to private doctor | 21 |
| Total number of patients using the Infirmary | 46 |
| Total number of patient days of Infirmary occupancy | 498 |

* Combined graduate and undergraduate
** Includes Class of 1971

TABLE III INFIRMARY

| Admissions | June 1, 1970-May 31, 1971 | June 1, 1971-May 31, 1972 |
|---|---|---|
| Medical | 372 | 405 |
| Surgical | 99 | 156 |
| Psychiatric | 35 | 38 |
| TOTAL | 506 | 599 |
| Patient Days | | |
| Faculty | 66 | 135 |
| Staff | 58 | 120 |
| Students | 1,638 | 2,032 |
| Employees | 156 | 480 |
| Student spouses | 131 | 201 |
| Others | 2 | 28 |
| TOTAL | 2,051 | 2,996 |

# Registrar

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.

TABLE I STUDENT REGISTRATION SINCE THE FOUNDING OF THE INSTITUTE*

| Year | Number of students | Year | Number of students | Year | Number of students |
|---|---|---|---|---|---|
| 1865-66 | 72 | 1901-02 | 1,415 | 1937-38 | 2,966 |
| 1866-67 | 137 | 1902-03 | 1,608 | 1938-39 | 3,093 |
| 1867-68 | 167 | 1903-04 | 1,528 | 1939-40 | 3,100 |
| 1868-69 | 172 | 1904-05 | 1,561 | 1940-41 | 3,138 |
| 1869-70 | 206 | 1905-06 | 1,466 | 1941-42 | 3,055 |
| 1870-71 | 224 | 1906-07 | 1,397 | 1942-43 | 3,048 |
| 1871-72 | 261 | 1907-08 | 1,415 | 1943-44 | 1,579 |
| 1872-73 | 348 | 1908-09 | 1,461 | 1944-45 | 1,198 |
| 1873-74 | 276 | 1909-10 | 1,479 | 1945-46 | 1,538 |
| 1874-75 | 248 | 1910-11 | 1,506 | 1946-47 | 5,172 |
| 1875-76 | 255 | 1911-12 | 1,559 | 1947-48 | 5,662 |
| 1876-77 | 215 | 1912-13 | 1,611 | 1948-49 | 5,433 |
| 1877-78 | 194 | 1913-14 | 1,685 | 1949-50 | 5,458 |
| 1878-79 | 188 | 1914-15 | 1,816 | 1950-51 | 5,171 |
| 1879-80 | 203 | 1915-16 | 1,900 | 1951-52 | 4,874 |
| 1880-81 | 253 | 1916-17 | 1,957 | 1952-53 | 5,074 |
| 1881-82 | 302 | 1917-18 | 1,698 | 1953-54 | 5,183 |
| 1882-83 | 368 | 1918-19 | 1,819 | 1954-55 | 5,348 |
| 1883-84 | 443 | 1919-20 | 3,078 | 1955-56 | 5,648 |
| 1884-85 | 579 | 1920-21 | 3,436 | 1956-57 | 6,000 |
| 1885-86 | 609 | 1921-22 | 3,505 | 1957-58 | 6,179 |
| 1886-87 | 637 | 1922-23 | 3,180 | 1958-59 | 6,259 |
| 1887-88 | 720 | 1923-24 | 2,949 | 1959-60 | 6,270 |
| 1888-89 | 827 | 1924-25 | 2,938 | 1960-61 | 6,289 |
| 1889-90 | 909 | 1925-26 | 2,813 | 1961-62 | 6,454 |
| 1890-91 | 937 | 1926-27 | 2,671 | 1962-63 | 6,695 |
| 1891-92 | 1,011 | 1927-28 | 2,712 | 1963-64 | 6,925 |
| 1892-93 | 1,060 | 1928-29 | 2,868 | 1964-65 | 7,151 |
| 1893-94 | 1,157 | 1929-30 | 3,066 | 1965-66 | 7,408 |
| 1894-95 | 1,183 | 1930-31 | 3,209 | 1966-67 | 7,567 |
| 1895-96 | 1,187 | 1931-32 | 3,188 | 1967-68 | 7,730 |
| 1896-97 | 1,198 | 1932-33 | 2,831 | 1968-69 | 7,764 |
| 1897-98 | 1,198 | 1933-34 | 2,606 | 1969-70 | 8,024 |
| 1898-99 | 1,171 | 1934-35 | 2,507 | 1970-71 | 7,799 |
| 1899-00 | 1,178 | 1935-36 | 2,540 | 1971-72 | 7,717 |
| 1900-01 | 1,277 | 1936-37 | 2,793 | | |

* 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

| Year | *In Regular Subjects | †In Other Subjects | Year | *In Regular Subjects | †In Other Subjects |
|---|---|---|---|---|---|
| 1948 | 2,146 | — | 1959 | 1,635 | 1,510 |
| 1949 | 1,875 | 171 | 1960 | 1,600 | 1,696 |
| 1950 | 1,852 | 259 | 1961 | 1,668 | 1,412 |
| 1951 | 1,861 | 813 | 1962 | 1,748 | 1,763 |
| 1952 | 1,689 | 832 | 1963 | 1,808 | 1,397 |
| 1953 | 1,672 | 1,289 | 1964 | 1,882 | 1,492 |
| 1954 | 1,675 | 1,398 | 1965 | 2,090 | 1,568 |
| 1955 | 1,619 | 1,653 | 1966 | 2,054 | 1,787 |
| 1956 | 1,553 | 2,497 | 1967 | 2,218 | 1,829 |
| 1957 | 1,548 | 1,757 | 1968 | 2,490 | 1,842 |
| 1958 | 1,650 | 1,752 | 1969 | 2,241 | 1,938 |
| | | | 1970 | 2,185 | 1,666 |
| | | | 1971 | 2,197 | 1,109 |

* 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.

TABLE II THE ACADEMIC STAFF COUNT

| | Professors | Administration; also Professors | Associate Professors | Assistant Professors | Lecturers* | Senior Research Scientists | Instructors | Coaches | Technical Instructors | Research Associates | Technical Assistants | Research Assistants | Teaching Assistants | Instructor Grad | Total | Visiting Professors | Others† |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | | | | | | | | | | | | | | |
| Architecture | 9 | 1 | 10 | 11 | 6 | - | 10 | - | 2 | 1 | - | 3 | 4 | - | 57 | 6 | 5 |
| Urban Studies and Planning | 6 | 3 | 8 | 7 | 7 | - | 1 | - | - | 2 | - | 5 | 1 | 4 | 44 | 4 | 12 |
| Total | 15 | 4 | 18 | 18 | 13 | - | 11 | - | 2 | 3 | - | 8 | 5 | 4 | 101 | 10 | 17 |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | | | | | |
| Aeronautics and Astronautics | 22 | 3 | 14 | 7 | 11 | - | - | - | 2 | 3 | - | 106 | 1 | - | 169 | 1 | 11 |
| Chemical Engineering | 9 | 2 | 5 | 5 | 1 | - | - | - | 3 | 4 | - | 41 | 34 | - | 104 | 4 | 4 |
| Civil Engineering | 13 | 1 | 18 | 15 | 5 | - | - | - | 2 | 8 | - | 111 | 19 | 1 | 193 | 5 | 8 |
| Electrical Engineering | 46 | 2 | 33 | 24 | 27 | - | 2 | - | - | 10 | - | 141 | 90 | 13 | 388 | 8 | 25 |
| Mechanical Engineering | 25 | 3 | 20 | 8 | 13 | - | - | - | 5 | 12 | - | 117 | 3 | 1 | 207 | 1 | 8 |
| Metallurgy and Materials Science | 14 | 1 | 7 | 5 | 1 | - | - | - | 3 | 5 | - | 83 | 23 | - | 142 | 1 | 15 |
| Nuclear Engineering | 10 | 1 | 5 | 3 | - | - | - | - | - | 3 | - | 35 | 19 | 1 | 77 | - | 2 |
| Ocean Engineering | 11 | 1 | 4 | 3 | 3 | - | - | - | - | 3 | - | 24 | 9 | 2 | 60 | 1 | 9 |
| School Professors | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| Total | 150 | 15 | 106 | 70 | 61 | - | 2 | - | 15 | 48 | - | 658 | 198 | 18 | 1341 | 21 | 82 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | | | | |
| Economics | 11 | 3 | 3 | 4 | 2 | - | - | - | - | - | - | 10 | 13 | 6 | 52 | 3 | 10 |
| Foreign Literatures and Linguistics | 7 | 2 | 4 | 3 | 4 | - | 6 | - | - | - | - | 2 | 9 | - | 37 | 1 | 9 |
| Humanities | 17 | 1 | 12 | 19 | 6 | - | 11 | - | 2 | - | 4 | - | - | - | 72 | 3 | 3 |
| Philosophy | 7 | 1 | - | 6 | 1 | - | 4 | - | - | - | - | - | 3 | - | 22 | - | - |
| Political Science | 13 | 1 | 7 | 5 | 4 | - | 1 | - | - | - | 1 | 6 | 6 | - | 44 | 2 | 7 |
| Psychology | 4 | 1 | 5 | - | - | - | 1 | - | 1 | 20 | 1 | 16 | 3 | - | 52 | - | 6 |
| Total | 59 | 9 | 31 | 37 | 17 | - | 23 | - | 3 | 20 | 6 | 34 | 34 | 6 | 279 | 9 | 35 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | | | | | | | | | | | | | |
| Management | 18 | 3 | 16 | 19 | 14 | - | - | - | - | 6 | - | 10 | 16 | - | 102 | 5 | 8 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | | | | |
| Biology | 13 | 4 | 8 | 4 | 1 | 1 | 3 | - | - | 43 | 40 | 5 | 12 | - | 134 | 4 | 45 |
| Chemistry | 17 | 3 | 8 | 4 | 7 | 1 | 2 | - | 1 | 45 | 14 | 104 | 95 | - | 301 | 1 | 24 |
| Earth and Planetary Sciences | 9 | 1 | 4 | 8 | 1 | - | 1 | - | - | 17 | - | 54 | 12 | - | 107 | 2 | 9 |
| Mathematics | 34 | 2 | 7 | 8 | - | - | 27 | - | - | 5 | - | 11 | 50 | 2 | 146 | 3 | 6 |
| Meteorology | 7 | 2 | 1 | 2 | 3 | - | - | - | - | 7 | - | 40 | 2 | - | 64 | - | 3 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrition and Food Science | 9 | 3 | 10 | 8 | 8 | 1 | - | - | - | 20 | 13 | 29 | 1 | - | 102 | 3 | 16 |
| Physics | 50 | 4 | 16 | 20 | 9 | 8 | 3 | - | 4 | - | - | 122 | 37 | - | 273 | 2 | 22 |
| Total | 139 | 19 | 54 | 54 | 29 | 11 | 36 | - | 5 | 137 | 67 | 365 | 209 | 2 | 1127 | 15 | 125 |
| MISCELLANEOUS | | | | | | | | | | | | | | | | | |
| Aerospace Studies | - | - | - | - | - | - | 2 | - | 2 | - | - | - | - | - | 4 | 1 | - |
| Athletic | - | 1 | 6 | 6 | - | - | 9 | 18 | - | - | - | - | - | - | 40 | - | - |
| Medical | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | 113 |
| Military Science | - | - | - | - | - | - | - | - | 6 | - | - | - | - | - | 6 | 1 | 2 |
| Naval Science | - | - | - | - | - | - | - | - | 7 | - | - | - | - | - | 7 | 1 | - |
| Institute Professors | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | 2 | - |
| Administration | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - |
| Center for Advanced Visual Studies | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 |
| Center for International Studies | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | 2 | - | 14 |
| Center for Materials Science and Engineering | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Center for Space Research | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| Education Research Center | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Electronic Systems Laboratory | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Harvard-M.I.T. Health Sciences and Technology | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Laboratory for Nuclear Science | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Libraries | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 54 |
| M.I.T. Arteriosclerosis Center | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | - |
| National Magnet Laboratory | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Operations Research Center | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Research Laboratory of Electronics | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 43 |
| Student Activities | - | - | - | - | - | - | - | - | 2 | - | 7 | - | - | - | 9 | - | 3 |
| Urban Systems Laboratory | - | - | - | - | - | - | - | - | - | 6 | - | - | - | - | 6 | - | 5 |
| Total | 14 | 7 | 6 | 6 | - | - | 11 | 18 | 17 | 8 | 8 | - | - | - | 95 | 5 | 255 |
| Grand Total | 395[2] | 57[2] | 231[2] | 204[2] | 134[2] | 11 | 83[2] | 18 | 42[2] | 222[3] | 81 | 1075 | 462[2] | 30[2] | 3045[5] | 65[4] | 522[4] |
| Faculty ex-officio | | | | | | | | | | | | | | | 36 | | |
| | | | | | | | | | | | | | | | 3081 | | |

The total Faculty is 950.

* Lecturers include 25 Professors and 1 Associate Professor emeriti.

[1] Includes guests, visiting Engineers, visiting Lecturers, visiting Instructors, visiting Scientists, visiting Social Scientists, Research Affiliates, Postdoctoral Associates, Fellows, Administrative Officers, Administrative Assistants, visiting Architects, Executive Officers, Special Assistants, visiting Scholars, Editors, Librarians, and Medical Doctors.

[2] Total Teaching Staff is 1,638.

[3] One Faculty and 221 non-faculty.

[4] Not included in preceding total.

[5] Visiting Professors include 37 Professors, 22 Associate Professors, and 6 Assistant Professors.

TABLE III CLASSIFICATION OF STUDENTS SINCE 1969

| Course | 1969-70 | | | | | 1970-71 | | | | | 1971-72 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | G | Total | 2 | 3 | 4 | G | Total | 2 | 3 | 4 | G | Total |
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | | | | | | | | | | | | |
| Architecture (IV) | 50 | 56 | 27 | 97 | 230 | 40 | 59 | 54 | 135 | 288 | 37 | 59 | 51 | 141 | 288 |
| Architecture (IV-A) Fifth Year | - | - | 9 | - | 9 | - | - | 2 | - | 2 | - | - | - | - | - |
| Architecture (IV-B) | - | 1 | - | - | 1 | - | 1 | 1 | - | 2 | - | 1 | 4 | - | 5 |
| Urban Studies and Planning (XI) | - | - | - | 138 | 138 | 10 | 15 | 7 | 129 | 161 | 11 | 12 | 26 | 149 | 198 |
| Total | 50 | 57 | 36 | 235 | 378 | 50 | 75 | 64 | 264 | 453 | 48 | 72 | 81 | 290 | 491 |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | | | |
| Aeronautics and Astronautics (XVI) | 47 | 45 | 60 | 242 | 394 | 27 | 35 | 49 | 213 | 324 | 16 | 15 | 39 | 189 | 259 |
| Aeronautics and Astronautics (XVI-B) (Cooperative) | - | 5 | 15 | - | 20 | - | 2 | 10 | - | 12 | - | 1 | 5 | - | 6 |
| Chemical Engineering (X) | 26 | 25 | 36 | 127 | 214 | 30 | 37 | 22 | 149 | 238 | 38 | 32 | 31 | 141 | 242 |
| Chemical Engineering (X-C) | - | - | - | - | - | 3 | - | - | - | 3 | 3 | 6 | 5 | - | 14 |
| Civil Engineering (I) | 29 | 32 | 33 | 197 | 291 | 20 | 48 | 31 | 213 | 312 | 27 | 29 | 43 | 227 | 326 |
| Electrical Engineering (VI-1) | 140 | 165 | 175 | 545 | 1121 | 127 | 119 | 197 | 476 | 1069 | 113 | 114 | 141 | 463 | 1046 |
| Electrical Science and Engineering (VI-2) | 2 | 29 | 40 | | | - | - | 33 | | | - | - | - | | |
| Electrical Engineering (VI-3) (Computer Science) | 25 | - | - | | | 52 | 69 | 6 | | | 73 | 70 | 72 | | |
| Electrical Engineering (VI-A) (Cooperative) | - | 33 | 40 | 38 | 111 | - | 28 | 42 | 38 | 108 | - | 27 | 31 | 51 | 109 |
| Mechanical Engineering (II) | 35 | 52 | 62 | 242 | 391 | 29 | 37 | 53 | 236 | 355 | 30 | 35 | 41 | 210 | 316 |
| Mechanical Engineering (II-A) | 1 | 5 | 3 | - | 9 | 1 | 15 | 18 | - | 34 | 4 | 6 | 17 | - | 27 |
| Mechanical Engineering (II-B) (Cooperative) | 1 | - | 1 | - | 2 | - | 1 | - | 1 | 1 | - | - | - | - | - |
| Textile Technology (II-T) | - | - | - | 11 | 11 | - | - | - | 10 | 10 | - | - | - | 11 | 11 |
| Metallurgy and Materials Science (III, III-A) | 18 | 15 | 20 | 151 | 204 | 6 | 26 | 15 | 146 | 193 | 18 | 9 | 26 | 133 | 186 |
| Nuclear Engineering (XXII) | - | - | - | 128 | 128 | - | - | - | 114 | 114 | - | - | - | 120 | 120 |
| Ocean Engineering (XIII) [2] | 6 | 5 | 3 | 71 | 85 | 7 | 5 | 3 | 59 | 74 | 10 | 9 | 5 | 71 | 95 |
| Ocean Engineering (XIII-W) (Woods Hole) | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 11 | 11 |
| Naval Construction and Engineering (XIII-A) | - | - | - | 73 | 73 | - | - | - | 65 | 65 | - | - | - | 60 | 60 |
| Shipping and Shipbuilding Management (XIII-B) | - | - | 2 | 3 | 5 | - | - | - | 3 | 3 | - | - | - | 2 | 2 |
| Center for Advanced Engineering Study (EN) | - | - | - | 38 | 38 | - | - | - | 31 | 31 | - | - | - | 25 | 25 |
| Total | 330 | 411 | 490 | 1866 | 3097 | 302 | 422 | 469 | 1754 | 2947 | 332 | 353 | 456 | 1714 | 2855 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | | |
| Economics (XIV) | 11 | 22 | 35 | 129 | 197 | 14 | 22 | 31 | 103 | 170 | 6 | 25 | 39 | 107 | 177 |
| Foreign Literatures and Linguistics (XXIII) | - | - | - | 45 | 45 | - | - | - | 39 | 39 | - | - | - | 40 | 40 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Humanities and Engineering (XXI-A) | 2 | 6 | 29 | 34 | 236 | 5 | 5 | 15 | 38 | 209 | - | 5 | 10 | - | 15 |
| Humanities and Science (XXI-B) | 31 | 63 | 71 | | | 14 | 55 | 77 | | | 20 | 30 | 68 | - | 118 |
| Philosophy (XXIV) | - | - | - | - | - | - | - | - | - | - | 1 | 6 | 5 | 27 | 39 |
| Political Science (XVII) | 12 | 32 | 41 | 91 | 176 | 2 | 19 | 40 | 82 | 143 | 10 | 14 | 24 | 74 | 122 |
| Psychology (IX) | - | - | - | 30 | 30 | - | - | - | 25 | 25 | - | - | - | 30 | 30 |
| Total | 56 | 123 | 176 | 329 | 684 | 35 | 101 | 163 | 287 | 586 | 37 | 80 | 146 | 278 | 541 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | | | | | | | | | | | |
| Management (XV) | 15 | 52 | 72 | 393 | 532 | 26 | 48 | 69 | 355 | 498 | 16 | 49 | 80 | 346 | 491 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | | |
| Biology (VII) | 42 | 61 | 45 | 119 | 267 | 66 | 73 | 67 | 117 | 323 | 94 | 96 | 87 | 105 | 382 |
| Biology (VII-A) | - | - | - | - | - | - | - | - | - | - | 8 | 11 | 11 | - | 30 |
| Biology (VII-W) (Woods Hole) | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 7 | 7 |
| Chemistry (V) | 37 | 34 | 30 | 275 | 376 | 43 | 48 | 37 | 251 | 379 | 42 | 47 | 43 | 214 | 346 |
| Earth and Planetary Sciences (XII, XII-A) | 17 | 14 | 11 | 106 | 148 | 20 | 16 | 18 | 73 | 127 | 12 | 22 | 21 | 73 | 128 |
| Earth and Planetary Sciences (XII-W) (Woods Hole) | - | - | - | - | - | - | - | - | 24 | 24 | - | - | - | 26 | 26 |
| Physical Sciences (XII-B) | 11 | 14 | 7 | - | 32 | 3 | 14 | 14 | - | 31 | 2 | 8 | 20 | - | 30 |
| Mathematics (XVIII) | 72 | 91 | 106 | 149 | 418 | 88 | 89 | 88 | 134 | 399 | 87 | 113 | 84 | 123 | 407 |
| Meteorology (XIX) | | - | - | 65 | 65 | - | - | - | - | 43 | - | - | - | 49 | 49 |
| Meteorology (XIX-W) (Woods Hole) | - | - | - | - | - | - | - | - | 15 | 15 | - | - | - | 11 | 11 |
| Nutrition and Food Science (XX) | - | - | - | 113 | 113 | - | - | - | 103 | 103 | - | - | - | 102 | 102 |
| Physics (VIII) | 124 | 151 | 103 | 300 | 678 | 99 | 125 | 142 | 258 | 624 | 87 | 97 | 113 | 242 | 539 |
| Total | 303 | 365 | 302 | 1127 | 2097 | 319 | 363 | 366 | 1029 | 2069 | 332 | 394 | 379 | 952 | 2057 |
| Undesignated | 269 | | | | 269 | 295 | | | | 295 | 282 | | | | 282 |
| First Year | 967 | | | | 967 | 951 | | | | 951 | 1000 | | | | 1000 |
| Grand Total | 967 | 1023 | 1008[3] | 1076[1,3] | 3950 | 8024 | 951 | 1027 | 1011[4] | 1131[1,4] | 3679 | 7799 | 1000 | 1047 | 948[5] | 1142[5] | 3580 | 7717 |
| (Not included in the above figures) | | | | | | | | | | | | | | | |
| Non-Institute Students from Harvard | - | - | 4 | 130 | 134 | 1 | 3 | 5 | 112 | 121 | 1 | 2 | 23 | 218 | 244 |
| Non-Institute Students from Wellesley | - | 54 | 57 | - | 141 | 46 | 93 | 109 | 4 | 252 | 56 | 71 | 135 | - | 262 |
| Non-Institute | - | - | - | - | - | 2 | - | 1 | 1 | 4[6] | - | - | - | - | - |

[1] This total includes fifth year in Architecture.

[2] Prior to 1971-72 Naval Architecture and Marine Engineering.

[3] These totals include 6 students in third year and 5 in fourth year on foreign study.

[4] These totals include 10 students in third year and 2 in fourth year on foreign study.

[5] These totals include 14 in third year and 2 in fourth year on foreign study; 2 in third year and 1 in fourth year on domestic study.

[6] Includes 1 non-Institute student from each of Boston College, Boston University, Brandeis University, University of Massachusetts.

TABLE III-A WOMEN STUDENTS BY SCHOOLS, COURSES, AND YEARS, 1971-72[1]

| Course | Year | | | | |
|---|---|---|---|---|---|
| | 2 | 3 | 4 | G | Total |
| SCHOOL OF ARCHITECTURE & PLANNING | | | | | |
| Architecture (IV) | 7 | 8 | 7 | 30 | 52 |
| Urban Studies & Planning (XI) | 3 | 2 | 1 | 36 | 42 |
| Total | 10 | 10 | 8 | 66 | 94 |
| SCHOOL OF ENGINEERING | | | | | |
| Aeronautics & Astronautics (XVI) | - | 1 | - | 3 | 4 |
| Chemical Engineering (X) | 5 | 3 | - | 3 | 11 |
| Civil Engineering (I) | 2 | 1 | 4 | 14 | 21 |
| Electrical Engineering (VI) | 11 | 5 | 7 | 17 | 40 |
| Mechanical Engineering (II) | - | 1 | 1 | 4 | 6 |
| Metallurgy & Materials Science (III) | 4 | 2 | 2 | 5 | 13 |
| Nuclear Engineering (XXII) | - | - | - | 1 | 1 |
| Ocean Engineering (XIII) | 1 | - | - | 1 | 2 |
| Center for Advanced Engineering Study (EN) | - | - | - | 1 | 1 |
| Total | 23 | 13 | 14 | 49 | 99 |
| SCHOOL OF HUMANITIES & SOCIAL SCIENCE | | | | | |
| Economics (XIV) | - | 2 | 5 | 8 | 15 |
| Foreign Literatures & Linguistics (XXIII) | - | - | - | 15 | 15 |
| Humanities & Engineering or Science (XXI-A, XXI-B) | 4 | 1 | 10 | - | 15 |
| Philosophy (XXIV) | - | - | - | 7 | 7 |
| Political Science (XVII) | 1 | 1 | 3 | 11 | 16 |
| Psychology (IX) | - | - | - | 6 | 6 |
| Total | 5 | 4 | 18 | 47 | 74 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | |
| Management (XV) | 1 | 2 | 2 | 19 | 24 |
| SCHOOL OF SCIENCE | | | | | |
| Biology (VII) | 18 | 17 | 11 | 41 | 87 |
| Chemistry (V) | 7 | 8 | 2 | 26 | 43 |
| Earth & Planetary Sciences (XII, XII-A, XII-W) | 1 | - | 1 | 9 | 11 |
| Physical Sciences (XII-B) | - | 2 | - | - | 2 |
| Mathematics (XVIII) | 9 | 19 | 3 | 7 | 38 |
| Meteorology (XIX) | - | - | - | 3 | 3 |
| Nutrition & Food Science (XX) | - | - | - | 27 | 27 |
| Physics (VIII) | 9 | 4 | 7 | 8 | 28 |
| Total | 44 | 50 | 24 | 121 | 239 |
| Undesignated | 40 | - | - | - | 40 |
| First Year Students 128 | - | - | - | - | 128 |
| Grand Total 128 | 123 | 79 | 66 | 302 | 698 |

[1] Included also in Table III

TABLE III-B SPECIAL STUDENTS BY SCHOOLS, COURSES, AND YEARS, 1971-72[1]

| Course | Year | | | | |
|---|---|---|---|---|---|
| | 2 | 3 | 4 | G | Total |
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | | |
| Architecture (IV) | 2 | 1 | 2 | 23 | 28 |
| Urban Studies and Planning (XI) | - | - | - | 40 | 40 |
| Total | 2 | 1 | 2 | 63 | 68 |
| SCHOOL OF ENGINEERING | | | | | |
| Aeronautics and Astronautics (XVI) | - | - | - | 27 | 27 |
| Chemical Engineering (X) | - | - | - | 3 | 3 |
| Civil Engineering (I) | - | 1 | - | 30 | 31 |
| Electrical Engineering (VI, VI-3) | - | 2 | - | 54 | 56 |
| Mechanical Engineering (II) | - | - | - | 6 | 6 |
| Metallurgy and Materials Science (III) | - | - | - | 2 | 2 |
| Nuclear Engineering (XXII) | - | - | - | - | - |
| Ocean Engineering (XIII) | 1 | - | - | 7 | 8 |
| Center for Advanced Engineering Study (EN) | - | - | - | 25 | 25 |
| Total | 1 | 3 | - | 154 | 158 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | |
| Economics (XIV) | - | - | - | 5 | 5 |
| Foreign Literatures and Linguistics (XXIII) | - | - | - | 5 | 5 |
| Humanities and Engineering or Science (XXI-A, XXI-B) | - | - | - | - | - |
| Philosophy (XXIV) | - | - | - | 1 | 1 |
| Political Science (XVII) | - | - | 1 | 15 | 16 |
| Psychology (IX) | - | - | - | 1 | 1 |
| Total | - | - | 1 | 27 | 28 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | |
| Management (XV) | - | 1 | - | 33 | 34 |
| SCHOOL OF SCIENCE | | | | | |
| Biology (VII) | 1 | - | - | 9 | 10 |
| Chemistry (V) | - | - | - | - | - |
| Earth and Planetary Sciences (XII, XII-A, XII-W) | - | - | - | 7 | 7 |
| Physical Sciences (XII-B) | - | - | - | - | - |
| Mathematics (XVIII) | - | - | 3 | 5 | 8 |
| Meteorology (XIX) | - | - | - | 8 | 8 |
| Nutrition and Food Science (XX) | - | - | - | 10 | 10 |
| Physics (VIII) | - | - | - | 14 | 14 |
| Total | 1 | - | 3 | 53 | 57 |
| Undesignated | 65 | | | | 65 |
| First Year Students | 3 | | | | 3 |
| Grand Total | 3 | 69 | 5 | 6 | 330 | 413 |

[1] Included also in Table III

TABLE IV CONTINUED, FORMER, AND NEW STUDENTS

| | 1967-68 | 1968-69 | 1969-70 | 1970-71 | 1971-72 |
|---|---|---|---|---|---|
| Continued Students | | | | | |
| Undergraduate and graduate students registered at the end of the last academic year (including Special Students) | 5,368 | 5,426 | 5,471 | 5,474 | 5,332 |
| Non-continued Students | | | | | |
| 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) | 225 | 260 | 308 | 304 | 291 |
| Undergraduate students who enrolled for the first time since secondary school (excluding Special Students) | 912 | 963 | 956 | 942 | 979 |
| Undergraduate students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding Special Students) | 75 | 85 | 98 | 102 | 90 |
| Graduate students who enrolled for the first time at the Institute (excluding Special Students) | 890 | 756 | 883 | 759 | 786 |
| Special Undergraduate and Graduate Students with no previous Institute registration | 260 | 274 | 308 | 218 | 239 |
| Total | 7,730 | 7,764 | 8,024 | 7,799 | 7,717 |

TABLE V REGULAR STUDENTS FROM OTHER COLLEGES AND GRADUATES OF M.I.T. CLASSIFIED BY SCHOOLS AND COURSES, 1971-72

| | Entered with no previous degree | Entered with Bachelor's degree from other colleges | | Entered Graduate School with Bachelor's degree from M.I.T. |
|---|---|---|---|---|
| | | Undergraduate | Graduate | |
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | |
| Architecture (IV, IV-B) | 17 | - | 91 | 27 |
| Urban Studies and Planning (XI) | - | - | 100 | 9 |
| Total | 17 | - | 191 | 36 |
| SCHOOL OF ENGINEERING | | | | |
| Aeronautics and Astronautics (XVI) | 10 | - | 117 | 45 |
| Chemical Engineering (X) | 17 | - | 105 | 33 |
| Civil Engineering (I) | 9 | - | 152 | 45 |
| Electrical Engineering (VI, VI-1, VI-3, VI-A) | 61 | 1 | 239 | 221 |
| Mechanical Engineering (II, II-A, II-T) | 14 | 2 | 169 | 46 |
| Metallurgy and Materials Science (III, III-A) | 1 | - | 95 | 36 |
| Naval Construction and Engineering (XIII-A) | - | - | 59 | 1 |
| Nuclear Engineering (XXII) | - | - | 104 | 16 |
| Ocean Engineering (XIII, XIII-W) | 6 | - | 65 | 10 |
| Shipping and Shipbuilding Management (XIII-B) | - | - | 1 | 1 |
| Total | 118 | 3 | 1,106 | 454 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | |
| Economics (XIV) | 2 | - | 97 | 5 |
| Foreign Literatures and Linguistics (XXIII) | - | - | 34 | 1 |
| Humanities and Engineering or Science (XXI-A, XXI-B) | 4 | - | - | - |
| Philosophy (XXIV) | - | - | 23 | 3 |
| Political Science (XVII) | 2 | - | 49 | 10 |
| Psychology (IX) | - | - | 23 | 6 |
| Total | 8 | - | 226 | 25 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | |
| Management (XV) | 12 | - | 251 | 62 |
| SCHOOL OF SCIENCE | | | | |
| Biology (VII, VII-A, VII-W) | 14 | - | 95 | 8 |
| Chemistry (V) | 5 | - | 213 | 1 |
| Earth and Planetary Sciences (XII, XII-A, XII-W) | 4 | - | 78 | 14 |
| Mathematics (XVIII) | 25 | - | 94 | 24 |
| Meteorology (XIX, XIX-W) | - | - | 43 | 9 |
| Nutrition and Food Science (XX) | - | - | 80 | 12 |
| Physics (VIII) | 27 | - | 158 | 70 |
| Total | 75 | - | 761 | 138 |
| Undesignated | 5 | - | - | - |
| First Year | 1 | - | - | - |
| Grand Total | 236 | 3 | 2,535 | 715 |

TABLE VI LIST OF COLLEGES AND UNIVERSITIES WITH NUMBER OF GRADUATES ENTERING THE INSTITUTE AS REGULAR STUDENTS, 1971-72[1]

| United States | | | |
|---|---|---|---|
| Air Force Institute of Technology | 1 | Florida, University of | 4 |
| Alabama, University of | 1 | Florida Atlantic University | 1 |
| Albuquerque, University of | 1 | Florida Presbyterian College | 1 |
| Antioch College | 3 | Fordham University | 2 |
| Arizona, University of | 1 | | |
| Arkansas, University of | 4 | General Motors Institute | 2 |
| | | George Washington University | 4 |
| Bentley College | 1 | Georgetown University | 1 |
| Boston College | 6 | Georgia Institute of Technology | 3 |
| Boston University | 5 | Georgia Southern College | 1 |
| Bowdoin College | 1 | Gonzaga University | 1 |
| Brandeis University | 5 | | |
| Bridgeport, University of | 1 | Harvard University | 29 |
| Brigham Young University | 3 | Harvey Mudd College | 2 |
| Brown University | 10 | Haverford College | 1 |
| | | Hawaii, University of | 1 |
| California, University of, Berkeley | 14 | Houston, University of | 1 |
| California, University of, Davis | 3 | Howard University | 2 |
| California, University of, L.A. | 7 | | |
| California, University of, San Diego | 5 | Idaho, University of | 1 |
| California, University of, Santa Barbara | 2 | Illinois, University of | 6 |
| California, University of, Santa Cruz | 1 | Illinois Institute of Technology | 5 |
| California Institute of Technology | 5 | Indiana University | 1 |
| California State College, Long Beach | 1 | Indiana University of Pennsylvania | 1 |
| California State College, Pennsylvania | 1 | | |
| California State Polytechnic College | 3 | Jamestown College | 1 |
| Carleton College | 1 | Johns Hopkins University | 3 |
| Carnegie-Mellon University | 6 | | |
| Case Western Reserve University | 6 | Kansas, University of | 2 |
| Catholic University of America | 2 | Kent State University | 1 |
| Chicago, University of | 7 | | |
| Cincinnati, University of | 1 | Lawrence University | 2 |
| Citadel, The | 1 | Lehigh University | 5 |
| City College, The | 9 | Linfield College | 1 |
| Clarkson College of Technology | 5 | Louisiana State University, New Orleans | 1 |
| Colgate University | 1 | Lowell Technological Institute | 3 |
| Colorado, University of | 2 | | |
| Colorado School of Mines | 1 | Macalester College | 1 |
| Columbia University | 9 | Maine, University of | 2 |
| Connecticut, University of | 1 | Manhattan College | 3 |
| Cooper Union, The | 8 | Marquette University | 2 |
| Cornell University | 21 | Maryland, University of | 2 |
| | | Massachusetts Institute of Technology | 216 |
| Dartmouth College | 2 | Miami University | 2 |
| Delaware, University of | 2 | Michigan, University of | 10 |
| Denver, University of | 2 | Michigan State University | 4 |
| Detroit, University of | 1 | Minnesota, University of | 6 |
| Duke University | 3 | Mississippi Valley State College | 1 |
| | | Missouri, University of, St. Louis | 1 |
| Emmanuel College | 1 | Morgan State College | 1 |
| | | Nebraska, University of | 3 |
| Fairleigh Dickinson University | 1 | Nebraska Wesleyan University | 2 |
| Federal City College | 1 | New Hampshire, University of | 4 |

[1] Graduates of 179 colleges and universities in the United States and 130 foreign colleges entered the Institute.

TABLE VI continued

| | | | |
|---|---|---|---|
| New Mexico, University of | 1 | Tennessee Technological University | 1 |
| New Mexico State University | 1 | Texas, University of, Austin | 5 |
| New York University | 6 | Texas Southern University | 1 |
| Newton College of the Sacred Heart | 1 | Thomas Moore College | 1 |
| North Carolina, University of | 3 | Toledo, University of | 1 |
| North Carolina State University at Raleigh | 4 | Tougaloo College | 1 |
| North Carolina Agricultural and Technical State University | 1 | Trinity College, Vermont | 1 |
| Northeastern University | 12 | Tufts University | 6 |
| Northwestern University | 3 | Tulane University | 4 |
| Notre Dame, University of | 2 | Union College and University | 2 |
| | | Union Theological Seminary | 1 |
| Oberlin College | 3 | U.S. Coast Guard Academy | 5 |
| Occidental College | 1 | U.S. Merchant Marine Academy | 2 |
| Ohio State University | 2 | U.S. Military Academy | 12 |
| Oklahoma, University of | 2 | U.S. Naval Academy | 10 |
| Oklahoma State University | 2 | Utah, University of | 5 |
| Oregon, University of | 1 | Utah State University | 1 |
| | | Vanderbilt University | 1 |
| Pennsylvania, University of | 9 | Villanova University | 2 |
| Pennsylvania State University | 5 | Virginia, University of | 2 |
| Polytechnic Institute of Brooklyn | 8 | Virginia Military Institute | 1 |
| Pomona College | 1 | Virginia Polytechnic Institute | 4 |
| Princeton University | 8 | | |
| Providence College | 1 | Washington, University of | 8 |
| Purdue University | 7 | Washington State University | 1 |
| | | Wayne State University | 3 |
| Radcliffe College | 2 | Wellesley College | 3 |
| Rensselaer Polytechnic Institute | 4 | Wesleyan University | 3 |
| Rhode Island, University of | 1 | West Virginia University | 1 |
| Rice University | 6 | Wichita State University | 1 |
| Ripon College | 1 | Wilkes College | 1 |
| Roosevelt University | 1 | Williams College | 2 |
| Rose Polytechnic Institute | 1 | Wisconsin, University of | 7 |
| Rutgers, The State University | 5 | Wisconsin State University | 1 |
| | | Worcester Polytechnic Institute | 3 |
| St. Francis, Maine | 1 | | |
| St. John's University | 1 | Xavier University | 1 |
| St. Louis University | 1 | | |
| San Diego State College | 1 | Yale University | 9 |
| San Francisco State College | 1 | York College | 1 |
| Santa Clara, University of | 1 | | |
| Scranton, University of | 1 | Total U.S. | 781 |
| Shaw University | 1 | | |
| Simmons College | 1 | Foreign | |
| Smith College | 2 | | |
| South Carolina, University of | 1 | Air Force Academy (Greece) | 1 |
| Southern California, University of | 2 | American Institute of Beirut (Lebanon) | 1 |
| Southern Illinois University | 1 | Anotati Scholi Economikon Kai | |
| Stanford University | 8 | Emborikon Epistimon (Greece) | 1 |
| State University of New York, Stony Brook | 6 | Aston, University of (England) | 1 |
| Stevens Institute of Technology | 2 | Baghdad, University of (Iraq) | 1 |
| Swarthmore College | 1 | Banaras Hindu University (India) | 1 |
| | | Bangalore University (India) | 1 |

TABLE VI continued - Foreign Colleges and Universities

| | | | |
|---|---|---|---|
| Birla Institute of Technology and Science (India) | 2 | Imperial College of Science and Technology (England) | 1 |
| Bombay, University of (India) | 1 | Indian Institute of Management (India) | 1 |
| Bristol, University of (England) | 1 | Indian Institute of Technology (Bombay, India) | 3 |
| British Columbia, University of (Canada) | 3 | Indian Institute of Technology (Kanpur, India) | 2 |
| Calcutta, University of (India) | 1 | Indian Institute of Technology (Delhi, India) | 1 |
| Cambridge University (England) | 3 | Institut Europeen d'Administration des Affaires (France) | 1 |
| Carleton University (Canada) | 1 | Institut National Agronomique (France) | 1 |
| Chulalongkorn University (Thailand) | 1 | Instituto Militar de Engenharia (Brazil) | 1 |
| College Sainte-Marie (Canada) | 1 | Instituto politecnico nacional (Mexico) | 1 |
| Danmarks Tekniske Hojskola (Denmark) | 2 | Kauppakorkeakoulu (Finland) | 1 |
| De La Salle College (Philippines) | 1 | Keio Gijuku Daigaku (Japan) | 1 |
| Durham, University of (England) | 1 | Kytoa Kaigaku (Japan) | 6 |
| Ecole Centrale de Paris (France) | 1 | Kyushu Kogyo Daigaku (Japan) | 1 |
| Ecole Centrales des Arts et Manufactures (France) | 7 | Laval Universite (Canada) | 1 |
| Ecole des Hautes Etudes Commercials (Canada) | 1 | Leicester, University of (England) | 1 |
| Ecole Nationale de l'Aviation Civile (France) | 1 | Liverpool, University of (England) | 1 |
| Ecole Nationale des Ponts et Chausees (France) | 2 | London, University of (England) | 3 |
| Ecole Nationale Superieure de l'Aeronautique et de l'Espace (France) | 1 | McGill University (Canada) | 6 |
| Ecole Nationale Superieure de Mecanique (et d'Aerotechnique de Poitiers) (France) | 1 | Memorial University of Newfoundland (Canada) | 1 |
| Ecole Nationale Superieure de Techniques Avancees (France) | 1 | Montreal, University of (Canada) | 1 |
| Ecole Nationale Superieure des Mines de Saint-Etienne (France) | 1 | Moscow M. V. Lomonsov State University (U.S.S.R.) | 1 |
| Ecole Normale Superieure (France) | 1 | Nairobi, University of (Kenya) | 2 |
| Ecole Polytechnique (France) | 5 | National Taiwan University (Republic of China) | 4 |
| Ecole Polytechnique de l'Universite de Lausanne (Switzerland) | 1 | New South Wales, University of (Australia) | 1 |
| Ecole Polytechnique de Montreal (Canada) | 1 | Norges Tekniske Hogskole (Norway) | 1 |
| Edinburgh University (Scotland) | 1 | Ontario, University of (Canada) | 1 |
| Eidgenossiche Technische Hoshschule (Switzerland) | 4 | Orta-Dogu Teknik Universitesi (Turkey) | 2 |
| Escola Naval (Portugal) | 2 | Osaka Daigaku (Japan) | 1 |
| Escuela Naval del Peru (Peru) | 2 | Osaka Kogyo Daigaku (Japan) | 1 |
| Escuela Politecnica National (Ecuador) | 1 | Oxford University (England) | 5 |
| Ethnikon Metsovion Polytechneion Athinai (Greece) | 3 | Paris, Universite de (France) | 2 |
| Gakushuin Daigaku (Japan) | 2 | Philippine Military Academy (Philippines) | 1 |
| Ghana, University of (Ghana) | 1 | Politecnico di Milano (Italy) | 1 |
| Haile Selassie I University (Ethiopia) | 1 | Pontificia Universidade Catolica (Brazil) | 1 |
| Heriot-Watt University (Scotland) | 1 | Post-Graduate Naval School of Engineering (Greece) | 1 |
| Hiroshima Daigaku (Japan) | 1 | Puerto Rico, University of at Mayaguez (Puerto Rico) | 1 |
| Hitotsubashi Daigaku (Japan) | 2 | | |

TABLE VI continued - Foreign Colleges and Universities

| | |
|---|---|
| Queens University at Kingston (Canada) | 2 |
| Ruprecht-Karl-Universitat Heidelberg (West Germany) | 1 |
| Salford University (England) | 1 |
| Seoul Dae Hak Kyo (Korea) | 2 |
| Shizwoka Daigaku (Japan) | 1 |
| Sir George Williams University (Canada) | 1 |
| Sofiski Universitet (Bulgaria) | 1 |
| Strathclyde, University of (Scotland) | 1 |
| Surrey, University of (England) | 1 |
| Sussex, University of (England) | 1 |
| Taiwan, National University of (Republic of China) | 1 |
| Tatung Institute of Technology (Republic of China) | 2 |
| Technion (Israel) | 6 |
| Technische Hogeschool Delft (The Netherlands) | 4 |
| Technische Universitat Berlin (Germany) | 1 |
| Tokyo Daigaku (Japan) | 6 |
| Tokyo Kogyo Daigaku (Japan) | 1 |
| Toronto, University of (Canada) | 1 |
| Universidad catolica Andres Bello (Venezuela) | 1 |
| Universidad central de Venezuela (Venezuela) | 6 |
| Universidad de Buenos Aires (Argentina) | 1 |
| Universidad de Chile (Chile) | 2 |
| Universidad de Concepcion (Chile) | 1 |
| Universidad de la Republica (Uruguay) | 1 |
| Universidad de los Andes (Colombia) | 2 |
| Universidad del Valle (Colombia) | 1 |
| Universidad nacional autonoma de mexico (Mexico) | 2 |
| Universidad Pontificia Bolivariana (Colombia) | 1 |
| Universidad Technologica de Perira (Colombia) | 1 |
| Universidade de Sao Paulo (Brazil) | 1 |
| Universidade de Porto (Portugal) | 1 |
| Universidade Federal de Minas Gerais (Brazil) | 1 |
| Universidade Federal do Rio de Janeiro (Brazil) | 1 |
| Universita Degli Studi di Firenze (Italy) | 2 |
| Universita degli Studi di Napoli (Italy) | 2 |
| Universite Catholique de Louvain (Belgium) | 1 |
| Universite de Poitiers (France) | 1 |
| Universite Halles Aux Vins (France) | 1 |
| Universite Libre de Bruxelles (Belgium) | 1 |
| Universiteit van Amesterdam (The Netherlands) | 1 |
| Universitet i Oslo (Norway) | 1 |
| Universitet u Novom Sadu (Yugoslavia) | 2 |
| Uniwersytet Warszawski (Poland) | 1 |
| Victoria, University of (England) | 3 |
| Victoria, University of (Canada) | 1 |
| Waseda Daigaku (Japan) | 4 |
| Waterloo, University of (Canada) | 3 |
| Western Ontario, University of (Canada) | 2 |
| Witwatersrand, University of (South Africa) | 2 |
| York University (Canada) | 1 |
| Total Foreign | 221 |
| Grand Total | 1,002 |

TABLE VII GEOGRAPHIC DISTRIBUTION OF STUDENTS, 1971-72

| United States | Undergrad. | Grad. |
|---|---|---|
| Alabama | 22 | 13 |
| Alaska | 3 | 1 |
| Arizona | 13 | 11 |
| Arkansas | 6 | 6 |
| California | 176 | 158 |
| Colorado | 26 | 13 |
| Connecticut | 134 | 71 |
| Delaware | 16 | 7 |
| District of Columbia | 25 | 15 |
| Florida | 94 | 53 |
| Georgia | 33 | 9 |
| Hawaii | 28 | 8 |
| Idaho | 10 | 3 |
| Illinois | 158 | 92 |
| Indiana | 34 | 32 |
| Iowa | 23 | 13 |
| Kansas | 26 | 13 |
| Kentucky | 22 | 11 |
| Louisiana | 17 | 8 |
| Maine | 26 | 12 |
| Maryland | 145 | 64 |
| Massachusetts | 440 | 602 |
| Michigan | 95 | 53 |
| Minnesota | 38 | 27 |
| Mississippi | 5 | 6 |
| Missouri | 56 | 32 |
| Montana | 11 | 4 |
| Nebraska | 12 | 9 |
| Nevada | 4 | 1 |
| New Hampshire | 31 | 14 |
| New Jersey | 247 | 144 |
| New Mexico | 8 | 8 |
| New York | 788 | 467 |
| North Carolina | 26 | 18 |
| North Dakota | 1 | 3 |
| Ohio | 164 | 109 |
| Oklahoma | 15 | 12 |
| Oregon | 27 | 9 |
| Pennsylvania | 258 | 138 |
| Rhode Island | 26 | 17 |
| South Carolina | 14 | 12 |
| South Dakota | 9 | 4 |
| Tennessee | 36 | 13 |
| Texas | 81 | 61 |
| Utah | 7 | 15 |
| Vermont | 17 | 3 |
| Virginia | 95 | 48 |
| Washington | 40 | 28 |
| West Virginia | 8 | 9 |
| Wisconsin | 46 | 35 |
| Wyoming | 4 | 2 |
| U.S. Territories and Dependencies | | |
| Puerto Rico | 15 | 10 |
| Virgin Islands | 2 | - |
| U.S. Citizens Foreign Address | 65 | 65 |
| Total U.S. | 3,728 | 2,591 |
| Foreign Countries* | | |
| Aden | - | 3 |
| Afghanistan | - | 1 |
| Argentina | 2 | 14 |
| Australia | 1 | 9 |
| Austria | - | 1 |
| Belgium | - | 8 |
| Bermuda | 1 | - |
| Brazil | 4 | 28 |
| Bulgaria | - | 1 |
| Cameroon | 2 | 2 |
| Canada | 60 | 96 |
| Central Africa, Republic of | - | 2 |
| Ceylon | - | 2 |
| Chile | 1 | 14 |
| China, Republic of | 30 | 75 |
| Colombia | 10 | 17 |
| Costa Rica | 1 | - |
| Cuba | 13 | 7 |

* Country of citizenship

Table VII continued

| | Undergrad. | Grad. |
|---|---|---|
| Curacao | 1 | 1 |
| Cyprus | 4 | 1 |
| Czechoslovakia | 1 | 2 |
| Denmark | 1 | 2 |
| Dominican Republic | 1 | 2 |
| Ecuador | - | 4 |
| El Salvador | 2 | 2 |
| England | 16 | 46 |
| Ethiopia | 4 | - |
| Finland | 1 | 2 |
| France | - | 56 |
| Germany | 1 | 21 |
| Ghana | 5 | 7 |
| Greece | 12 | 34 |
| Guatemala | 1 | 3 |
| Guyana | - | 1 |
| Haiti | - | 1 |
| Hong Kong | 64 | 47 |
| Hungary | - | 1 |
| Iceland | 1 | 1 |
| India | 13 | 86 |
| Indonesia | 2 | 1 |
| Iran | 13 | 10 |
| Iraq | - | 1 |
| Ireland | - | 5 |
| Israel | 6 | 31 |
| Italy | 4 | 13 |
| Ivory Coast | - | 1 |
| Jamaica | 2 | 3 |
| Japan | 15 | 55 |
| Jordan | - | 3 |
| Kenya | 1 | 6 |
| Korea | 11 | 26 |
| Kuwait | 1 | - |
| Lebanon | 1 | 8 |
| Libya | 1 | - |
| Lithuania | - | 1 |
| Luxembourg | - | 1 |
| Malaysia | 10 | 3 |
| Mexico | 3 | 16 |
| Morocco | 1 | 1 |
| Nepal | - | 1 |
| Netherlands | 2 | 13 |
| New Zealand | 1 | 4 |
| Nicaragua | - | 2 |
| Niger | 1 | - |
| Nigeria | 1 | 6 |
| Norway | 5 | 14 |
| Pakistan | 17 | 7 |
| Panama | - | 1 |
| Peru | 5 | 8 |
| Philippines | 1 | 8 |
| Poland | 4 | 7 |
| Portugal | 1 | 7 |
| Quater | - | 1 |
| Rhodesia | 1 | - |
| Rumania | 2 | 1 |
| Saudi Arabia | 1 | 1 |
| Scotland | - | 4 |
| Sierra Leone | 1 | 1 |
| Singapore | 1 | 2 |
| South Africa, Republic of | - | 7 |
| Spain | 1 | 8 |
| Sweden | - | 3 |
| Switzerland | 1 | 9 |
| Tanzania | 4 | - |
| Thailand | 10 | 13 |
| Trinidad | - | 2 |
| Tunisia | - | 1 |
| Turkey | 5 | 19 |
| Uganda | - | 1 |
| United Arab Republic (Egypt) | 1 | 9 |
| Uruguay | 1 | 3 |
| Venezuela | 6 | 17 |
| Vietnam | 2 | 3 |
| Wales | - | 1 |
| Yugoslavia | - | 9 |
| Zambia | - | 2 |
| Zanzibar | - | 1 |
| Stateless | 10 | 8 |
| Total Foreign | 409 | 989 |
| Grand Total | 4,137 | 3,580 |

TABLE VIII NUMBER OF DEGREES AWARDED IN SEPTEMBER 1971, FEBRUARY 1972, AND JUNE 1972

| | S.B. | | | B.Arch.[1] | | | S.M. | | | M.Arch.[2] M.C.P. | | | Engineer | | | Ph.D. | | | Sc.D. | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June | Sept. | Feb. | June |
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | | | | | | | | | | | | | | | | | | | | | |
| Architecture | - | - | - | 4 | 2 | 19 | - | - | - | 3 | 1 | 20 | - | - | - | - | - | - | - | - | - | 7 | 3 | 39 |
| Undesignated | - | 3 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 3 |
| Art and Design | 4 | 3 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 3 | 35 |
| Urban Studies and Planning | - | 5 | 18 | - | - | - | - | - | - | 9 | 7 | 10 | - | - | - | 1 | 3 | 2 | - | - | - | 10 | 15 | 30 |
| Total | 4 | 11 | 56 | 4 | 2 | 19 | - | - | - | 12 | 8 | 30 | - | - | - | 1 | 3 | 2 | - | - | - | 21 | 24 | 107 |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | | | | | | | | | | | | |
| Aeronautics and Astronautics | 1 | 13 | 31 | - | - | - | 16 | 15 | 25 | - | - | - | - | 1 | 2 | 1 | 3 | 4 | - | 4 | 2 | 18 | 36 | 64 |
| Undesignated | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Ceramics | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| Chemical Engineering | 3 | 5 | 13 | - | - | - | 5 | 9 | 16 | - | - | - | 1 | 4 | 1 | 1 | - | 1 | 2 | 1 | 3 | 12 | 19 | 34 |
| Undesignated | - | 1 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 6 |
| Chemical Engineering Practice | - | - | - | - | - | - | - | 7 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 | 7 |
| Civil Engineering | 4 | 3 | 30 | - | - | - | 10 | 16 | 31 | - | - | - | - | 6 | 11 | 3 | 3 | 4 | 1 | 2 | 2 | 18 | 30 | 78 |
| Undesignated | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Electrical Engineering | 29 | 33 | 156 | - | - | - | 23 | 33 | 57 | - | - | - | 7 | 16 | 26 | 16 | 5 | 16 | 2 | 4 | 4 | 77 | 91 | 259 |
| Mechanical Engineering | 3 | 8 | 27 | - | - | - | 16 | 13 | 31 | - | - | - | 2 | 6 | 5 | 2 | 10 | 3 | - | 3 | 6 | 23 | 40 | 72 |
| Undesignated | 2 | 3 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 3 | 7 |
| Metallurgy and Materials Science | 4 | 2 | 8 | - | - | - | 5 | 1 | 6 | - | - | - | - | - | 2 | 9 | 1 | 6 | 3 | 5 | 2 | 21 | 9 | 24 |
| Undesignated | - | - | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 |
| Naval Architecture and Marine Engineering | - | - | 3 | - | - | - | 1 | 2 | 14 | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 2 | 2 | 18 |
| Nuclear Engineering | - | - | - | - | - | - | 7 | 8 | 12 | - | - | - | 3 | - | 2 | 4 | 4 | 3 | 2 | 4 | 6 | 16 | 16 | 23 |
| Ocean Engineering | - | - | 1 | - | - | - | 2 | - | 3 | - | - | - | 1 | - | 16 | - | - | 2 | 1 | 2 | - | 4 | 2 | 22 |
| Shipping and Shipbuilding Management | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Textile Technology | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Total | 46 | 68 | 293 | - | - | - | 85 | 105 | 207 | - | - | - | 15 | 33 | 66 | 36 | 26 | 39 | 11 | 25 | 25 | 193 | 257 | 630 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | | | | | | | | | | | |
| Economics | 2 | 6 | 32 | - | - | - | - | 1 | 2 | - | - | - | - | - | - | 12 | 4 | 7 | - | - | - | 14 | 11 | 41 |
| Humanities and Engineering | - | 2 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 4 |
| Humanities and Science | 4 | 11 | 45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 11 | 45 |
| Linguistics | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 2 | - | - | - | 3 | 1 | 2 |
| Philosophy | - | - | 4 | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | - | 2 | - | - | - | 1 | - | 7 |
| Political Science | 5 | 6 | 10 | - | - | - | 5 | 2 | - | - | - | - | - | - | - | 6 | 3 | 2 | - | - | - | 16 | 11 | 12 |
| Psychology | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 1 | 3 |
| Total | 11 | 25 | 95 | - | - | - | 5 | 3 | 5 | - | - | - | - | - | - | 22 | 9 | 14 | - | - | - | 38 | 37 | 114 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Management | 9 | 13 | 59 | - | - | - | 22 | 17 | 119 | - | - | - | - | - | - | 1 | 3 | 3 | - | - | - | 32 | 33 | 181 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Biochemical Engineering | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| Biochemistry | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| Biology | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | 10 | 13 | 8 | - | - | - | 10 | 13 | 12 |
| Undesignated | 1 | 3 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 35 |
| Chemistry | 1 | 6 | 37 | - | - | - | 6 | 2 | 2 | - | - | - | - | - | - | 22 | 14 | 16 | - | - | - | 29 | 22 | 55 |
| Earth and Planetary Sciences | 1 | 2 | 15 | - | - | - | 3 | 2 | 5 | - | - | - | - | - | - | 6 | 1 | 2 | - | - | 1 | 10 | 5 | 23 |
| Undesignated | 1 | 3 | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | 14 |
| Food Science and Technology | - | - | - | - | - | - | 3 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 1 |
| Life Sciences | 5 | 11 | 47 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | 11 | 47 |
| Mathematics | 5 | 11 | 73 | - | - | - | 3 | 1 | 3 | - | - | - | - | - | - | 10 | 1 | 14 | - | - | 1 | 18 | 13 | 91 |
| Meteorology | - | - | - | - | - | - | 1 | - | 5 | - | - | - | - | - | - | 1 | 1 | 2 | - | 1 | - | 2 | 2 | 7 |
| Nutrition and Food Science | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 2 | 2 | 1 | 1 | 5 | 2 | 3 |
| Nutritional Biochemistry and Metabolism | - | - | - | - | - | - | 2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | 1 |
| Oceanography | - | - | - | - | - | - | 2 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 3 | 1 |
| Physics | 6 | 8 | 93 | - | - | - | 3 | 3 | 7 | - | - | - | - | - | - | 28 | 12 | 15 | 1 | - | - | 38 | 23 | 115 |
| Total | 20 | 44 | 314 | - | - | - | 23 | 14 | 32 | - | - | - | - | - | - | 80 | 43 | 59 | 3 | 2 | 3 | 126 | 103 | 408 |
| Operations Research | - | - | - | - | - | - | 1 | 2 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 5 |
| Without Course Specification | - | - | - | - | - | - | 26 | 16 | 13 | - | - | - | - | - | - | - | - | - | - | - | - | 26 | 16 | 13 |
| AWARDED JOINTLY WITH WOODS HOLE OCEANOGRAPHIC INSTITUTION | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Earth and Planetary Sciences | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 1 | 1 |
| Meteorology | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 1 | - | - | 1 | 3 | 1 | 2 |
| Ocean Engineering | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 2 | - | - | - | - | - | - | 1 | - | 2 |
| Grand Total | 90 | 161 | 817 | 4 | 2 | 19 | 162 | 157 | 381 | 12 | 8 | 30 | 16 | 33 | 68 | 143 | 86 | 119 | 14 | 27 | 29 | 441 | 474 | 1,463 |

1 Degree of Bachelor in Architecture changed to degree of Master of Architecture in June, 1972.
2 Degree of Master in Architecture changed to degree of Master of Architecture in Advanced Studies in June, 1972.

# TABLE IX NUMBER OF DEGREES OF BACHELOR OF SCIENCE AWARDED*

All statistics are arranged by Schools 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.

| | Total by decades | | | | | | | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1868-70 | 1871-80 | 1881-90 | 1891-1900 | 1901-10 | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972** |
| SCHOOL OF ARCHITECTURE AND PLANNING [1] | | | | | | | | | | | | | | | | | | |
| Architecture | - | 12 | 24 | 162 | 188 | 233 | 223 | 23 | - | - | - | - | 865 | - | - | - | - | - |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 2 | 6 | 8 | - | - | 2 | - | 6 |
| Architectural Engineering [2] | - | - | - | - | - | - | 108 | 64 | - | - | - | - | 172 | - | - | - | - | - |
| Art and Design | - | - | - | - | - | - | - | - | - | - | 26 | 84 | 110 | 1 | 10 | 14 | 46 | 38 |
| Urban Studies | - | - | - | - | - | - | - | - | - | - | - | 32 | 32 | - | - | - | 9 | 23 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 1 | - |
| Total | - | 12 | 24 | 162 | 188 | 233 | 331 | 87 | - | - | 28 | 123 | 1188 | 1 | 10 | 16 | 56 | 67 |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | | | | | | |
| Aeronautics and Astronautics [11] | - | - | - | - | - | - | 68 | 287 | 526 | 395 | 556 | 83 | 1915 | 74 | 65 | 57 | 39 | 44 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 1 |
| Building Engineering and Construction | - | - | - | - | - | - | 32 | 99 | 114 | 131 | - | - | 376 | - | - | - | - | - |
| Chemical Engineering | - | - | - | 91 | 123 | 372 | 571 | 434 | 740 | 726 | 421 | 40 | 3518 | 21 | 23 | 26 | 22 | 18 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 3 | 8 | 11 | - | - | 3 | 1 | 7 |
| Chemical Engineering Practice | - | - | - | - | - | - | 99 | 90 | 95 | 108 | 1 | - | 393 | - | - | - | - | - |
| Civil Engineering | 12 | 84 | 86 | 256 | 407 | 504 | 653 | 284 | 272 | 457 | 252 | 58 | 3325 | 30 | 18 | 16 | 25 | 33 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 7 | 11 | 18 | - | 1 | 6 | 8 | 3 |
| Electrical Engineering (including VI-A) | - | - | 72 | 335 | 349 | 468 | 1000 | 719 | 1218 | 1518 | 1941 | 398 | 8018 | 151 | 198 | 189 | 209 | 189 |
| Electrochemical Engineering [3] | - | - | - | - | 28 | 84 | 133 | 56 | - | - | - | - | 301 | - | - | - | - | - |
| General Engineering | - | - | - | - | - | 6 | 226 | 222 | 230 | 133 | - | - | 817 | - | - | - | - | - |
| Mechanical Engineering | 5 | 40 | 147 | 329 | 502 | 623 | 797 | 602 | 1164 | 1049 | 563 | 78 | 5899 | 40 | 40 | 44 | 43 | 35 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 12 | 28 | 40 | - | 2 | 10 | 18 | 10 |
| Metallurgy and Materials Science [4] | - | - | - | - | - | - | - | 52 | 194 | 311 | 186 | 24 | 767 | 10 | 20 | 12 | 14 | 10 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 1 | 11 | 12 | - | - | 1 | 4 | 7 |
| Military Engineering | - | - | - | - | - | - | 1 | 4 | - | - | - | - | 5 | - | - | - | - | - |
| Mining Engineering and Metallurgy | 8 | 44 | 64 | 74 | 250 | 129 | 174 | 137 | - | - | - | - | 880 | - | - | - | - | - |

* All Footnotes follow the end of the Table.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Naval Architecture and Marine Engineering | - | - | - | 43 | 133 | 69† | 100 | 173 | 234 | 139 | 69 | 8 | 968 | 4 | 8 | 3 | 5 | 3 |
| Ocean Engineering | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 1 |
| Sanitary Engineering | - | - | - | 29 | 54 | 123 | 34 | 20 | 4 | - | - | - | 264 | - | - | - | - | - |
| Total | 25 | 168 | 369 | 1157 | 1846 | 2378 | 3888 | 3179 | 4791 | 4967 | 4012 | 749 | 27,529 | 330 | 375 | 367 | 388 | 361 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | | | | | |
| Economics | - | - | - | - | - | - | - | - | - | - | 129 | 61 | 190 | 31 | 39 | 28 | 23 | 38 |
| Economics, Politics, and Engineering or Science | - | - | - | - | - | - | - | - | 61 | 152 | 100 | - | 313 | - | - | - | - | - |
| Humanities and Engineering or Science [5] | - | - | - | - | - | - | - | - | - | 49 | 412 | 125 | 586 | 36 | 40 | 87 | 63 | 62 |
| Philosophy | - | - | - | - | - | - | - | - | - | - | - | 4 | 4 | - | - | - | - | 4 |
| Political Science [9] | - | - | - | - | - | - | - | - | - | - | 114 | 40 | 154 | 26 | 23 | 27 | 24 | 16 |
| Total | - | - | - | - | - | - | - | - | 61 | 201 | 755 | 230 | 1247 | 93 | 102 | 142 | 110 | 120 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT [6] | | | | | | | | | | | | | | | | | | |
| Business and Engineering Administration | - | - | - | - | - | 142 | 872 | 641 | 909 | 732 | - | - | 3296 | - | - | - | - | - |
| Management [10] | - | - | - | - | - | - | - | - | - | 172 | 565 | 147 | 884 | 49 | 55 | 76 | 75 | 72 |
| Total | - | - | - | - | - | 142 | 872 | 641 | 909 | 904 | 565 | 147 | 4180 | 49 | 55 | 76 | 75 | 72 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | | | | | |
| Biology [7] | - | 3 | 11 | 25 | 27 | 49 | 57 | 129 | 74 | 116 | 16 | - | 507 | - | - | - | - | - |
| Undesignated | - | - | - | - | - | - | - | - | - | - | - | 51 | 51 | - | - | - | 13 | 38 |
| Chemistry | 2 | 27 | 80 | 154 | 151 | 111 | 141 | 166 | 232 | 217 | 307 | 80 | 1658 | 34 | 36 | 25 | 37 | 43 |
| Earth and Planetary Sciences [8] | - | - | - | 8 | 6 | 3 | 36 | 22 | 32 | 141 | 109 | 34 | 391 | 15 | 15 | 8 | 17 | 17 |
| Undesignated | - | - | - | - | - | - | - | - | - | - | 7 | 34 | 41 | - | 1 | 6 | 17 | 17 |
| Food Technology and Biochemical Engineering | - | - | - | - | - | - | - | - | 35 | 62 | 11 | - | 108 | - | - | - | - | - |
| General Science or General Course | 2 | 11 | 17 | 49 | 20 | 26 | 17 | 73 | 58 | 62 | - | - | 335 | - | - | - | - | - |
| Life Sciences [7] | - | - | - | - | - | - | - | - | - | - | 291 | 108 | 399 | 45 | 42 | 46 | 50 | 58 |
| Mathematics | - | - | - | - | - | - | 19 | 48 | 72 | 220 | 831 | 163 | 1353 | 88 | 68 | 94 | 79 | 84 |
| Meteorology | - | - | - | - | - | - | - | - | 56 | 38 | - | - | 94 | - | - | - | - | - |
| Physics | - | 5 | 6 | 24 | 19 | 21 | 49 | 170 | 306 | 617 | 1079 | 223 | 2519 | 106 | 91 | 85 | 122 | 101 |
| Total | 4 | 46 | 114 | 260 | 223 | 210 | 319 | 608 | 868 | 1463 | 2651 | 693 | 7456 | 288 | 253 | 264 | 335 | 358 |
| Grand Total | 29 | 226 | 507 | 1579 | 2257 | 2963 | 5410 | 4515 | 6626 | 7535 | 8011 | 1942 | 41,600 | 761 | 795 | 865 | 964 | 978 |

Footnotes for Table IX



** Includes only February and June degrees.

† Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917.

1 See also Table XI.

2 Prior to 1923 degrees were awarded in Architecture.

3 Prior to 1909 this course was designated as Option 3 (Electrochemistry) of Physics.

4 Prior to 1938 these degrees were included in Mining Engineering and Metallurgy; changed from Metallurgy to Metallurgy and Materials Science, January, 1968.

5 Prior to 1958 these degrees were included in General Engineering and General Science or General Course.

6 Changed to Alfred P. Sloan School of Management after 1963.

7 Changed to Life Sciences beginning January, 1962.

8 Changed from Geology and Geophysics to Earth Sciences in February, 1961. Changed from Earth Sciences to Earth and Planetary Sciences in February, 1970.

9 Prior to September, 1965, these degrees were included in Economics, Politics, and Engineering or Science.

10 Prior to 1959, Business and Engineering Administration; changed from Industrial Management to Management in February, 1967.

11 Prior to 1960, Aeronautical Engineering.

TABLE X NUMBER OF DEGREES OF MASTER OF SCIENCE AWARDED*

| | Total by decades | | | | | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1886-90 | 1891-1900 | 1901-10 | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972** |
| SCHOOL OF ARCHITECTURE AND PLANNING[1] | | | | | | | | | | | | | | | | |
| Architecture | - | 8 | 45 | 31 | - | - | - | - | - | - | 84 | - | - | - | - | - |
| Architectural Engineering[2] | - | - | - | - | 9 | 10 | - | - | - | - | 19 | - | - | - | - | - |
| Total | - | 8 | 45 | 31 | 9 | 10 | - | - | - | - | 103 | - | - | - | - | - |
| SCHOOL OF ENGINEERING[12] | | | | | | | | | | | | | | | | |
| Aeronautics and Astronautics | - | - | - | 17 | 59 | 76 | 307 | 375 | 645 | 91 | 1570 | 63 | 32 | 71 | 51 | 40 |
| Building Engineering and Construction | - | - | - | - | - | - | 21 | 66 | 21 | - | 108 | - | - | - | - | - |
| Ceramics | - | - | - | - | - | 3 | 3 | 13 | 20 | 4 | 43 | 2 | 2 | 2 | 2 | 2 |
| Chemical Engineering | - | 3 | 2 | 18 | 69 | 152 | 275 | 467 | 398 | 54 | 1438 | 46 | 28 | 26 | 29 | 25 |
| Chemical Engineering Practice | - | - | - | - | 245 | 284 | 241 | 256 | 102 | 32 | 1160 | 10 | 7 | 13 | 18 | 14 |
| Civil Engineering | - | 1 | 4 | 27 | 53 | 179 | 194 | 350 | 548 | 93 | 1449 | 67 | 44 | 46 | 46 | 47 |
| Electrical Engineering (including VI-A) | - | - | 7 | 43 | 462 | 474 | 546 | 1164 | 1530 | 184 | 4410 | 164 | 137 | 138 | 94 | 90 |
| Electrochemical Engineering | - | - | - | 4 | 16 | 8 | - | - | - | - | 28 | - | - | - | - | - |
| Fuel and Gas Engineering | - | - | - | - | 15 | 11 | - | - | - | - | 26 | - | - | - | - | - |
| Mechanical Engineering | - | 1 | 8 | 22 | 100 | 175 | 357 | 525 | 690 | 121 | 2031 | 73 | 72 | 72 | 77 | 44 |
| Metallurgy | - | - | - | - | 8 | 36 | 92 | 230 | 205 | 27 | 597 | 11 | 9 | 10 | 19 | 7 |
| Mining Engineering | - | - | - | 9 | 8 | 16 | - | - | - | - | 33 | - | - | - | - | - |
| Naval Architecture and Marine Engineering | - | - | 2 | 1 | 5 | 20 | 60 | 165 | 281 | 33 | 568 | 26 | 31 | 28 | 18 | 16 |
| Naval Construction and Engineering | - | - | 39 | 48 | 101 | 89 | 206 | - | - | - | 483 | - | - | - | - | - |
| Nuclear Engineering[3] | - | - | - | - | - | - | - | 67 | 282 | 42 | 391 | 25 | 31 | 37 | 22 | 20 |
| Ocean Engineering | - | - | - | - | - | - | - | - | 3 | 9 | 12 | - | - | 3 | 6 | 3 |
| Petroleum Engineering | - | - | - | - | - | 5 | - | - | - | - | 5 | - | - | - | - | - |
| Railroad Engineering | - | - | - | - | - | 14 | - | - | - | - | 14 | - | - | - | - | - |
| Sanitary Engineering | - | - | 2 | 8 | 3 | 10 | 53 | 99 | 16 | - | 191 | - | - | - | - | - |
| Shipping and Shipbuilding Management | - | - | - | - | - | - | - | 4 | 15 | 5 | 24 | 3 | - | 1 | 2 | 3 |
| Textile Technology | - | - | - | - | - | 1 | 31 | 34 | 20 | 2 | 56 | 2 | 3 | 1 | 1 | 1 |
| Total | - | 5 | 64 | 197 | 1144 | 1553 | 2386 | 3815 | 4776 | 697 | 14,637 | 492 | 396 | 448 | 385 | 312 |

* Footnotes follow the Table.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | | | |
| Economics[8] | - | - | - | - | - | - | - | - | 19 | 4 | 23 | 4 | 6 | 4 | 1 | 3 |
| Economics, Politics, and Engineering or Science[11] | - | - | - | - | - | 12 | 16 | 19 | 10 | - | 57 | - | - | - | - | - |
| Linguistics | - | - | - | - | - | - | - | - | 1 | 1 | 2 | - | - | - | 1 | - |
| Philosophy | - | - | - | - | - | - | - | - | 2 | 1 | 3 | - | - | 2 | - | 1 |
| Political Science[8] | - | - | - | - | - | - | - | - | 25 | 11 | 36 | 3 | 6 | 9 | 9 | 2 |
| Psychology[4] | - | - | - | - | - | - | - | - | 7 | 2 | 9 | - | - | 1 | - | 2 |
| Total | - | - | - | - | - | 12 | 16 | 19 | 64 | 19 | 130 | 7 | 12 | 16 | 11 | 8 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT[5] | | | | | | | | | | | | | | | | |
| Management[9] | - | - | - | - | 4 | 60 | 122 | 581 | 1274 | 312 | 2353 | 128 | 131 | 159 | 176 | 136 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | | | |
| Biology[13] | - | 1 | 1 | 10 | 1 | 19 | 25 | 34 | 21 | 10 | 122 | 1 | 4 | 4 | 4 | 6 |
| Chemistry | 2 | 3 | 7 | 22 | 32 | 51 | 53 | 46 | 97 | 16 | 329 | 12 | 8 | 11 | 12 | 4 |
| Earth and Planetary Sciences[10] | - | - | - | - | - | - | - | - | 7 | 13 | 20 | - | - | 7 | 6 | 7 |
| General Science | - | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| Geology and Geophysics[10] | - | - | 2 | 5 | 21 | 15 | 17 | 48 | 71 | - | 179 | - | - | - | - | - |
| Mathematics | - | - | - | 2 | 9 | 25 | 45 | 96 | 73 | 12 | 262 | 10 | 10 | 12 | 8 | 4 |
| Meteorology[7] | - | - | - | - | - | 35 | 99 | 118 | 87 | 10 | 349 | 6 | 5 | 6 | 5 | 5 |
| Nutritional Biochemistry and Metabolism[6] | - | - | - | - | - | - | 12 | 51 | 125 | 15 | 203 | 19 | 17 | 10 | 9 | 6 |
| Oceanography | - | - | - | - | - | - | - | - | 28 | 10 | 38 | 5 | 2 | 1 | 6 | 4 |
| Physics | - | 3 | 2 | 2 | 16 | 40 | 50 | 121 | 138 | 32 | 404 | 6 | 18 | 22 | 22 | 10 |
| Total | 2 | 8 | 12 | 41 | 79 | 185 | 301 | 514 | 647 | 118 | 1907 | 72 | 73 | 73 | 72 | 46 |
| Operations Research | - | - | - | - | - | - | - | - | - | 15 | 15 | - | - | - | 8 | 7 |
| Without Course Specification | - | - | - | 5 | 308 | 263 | 123 | 357 | 300 | 85 | 1441 | 29 | 48 | 44 | 56 | 29 |
| Grand Total | 2 | 21 | 121 | 274 | 1544 | 2083 | 2948 | 5286 | 7061 | 1246 | 20,586 | 728 | 660 | 740 | 708 | 538 |

** 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 Includes degrees in Biochemical Engineering and in Food Science and Technology.

7 Considered Engineering until 1956.

8 Prior to September, 1965, these degrees were included in Economics, Politics, and Engineering or Science.

9 Prior to February, 1967, Industrial Management.

10 Changed to Earth and Planetary Sciences beginning February, 1970.

11 Includes 6 degrees in Political Science awarded 1965.

12 Prior to 1960, Aeronautical Engineering.

13 Includes degrees in Biochemistry.

TABLE XI NUMBER OF DEGREES OF BACHELOR AND MASTER IN ARCHITECTURE AND BACHELOR AND MASTER IN CITY PLANNING AWARDED

| | Total by decades | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972* |
| Bachelor in Architecture[2] | - | 146 | 126 | 257 | 211 | 24 | 764 | 24 | 20 | 16 | 21 | 3 |
| Bachelor in City Planning[1] | - | 14 | 13 | 4 | - | - | 31 | - | - | - | - | - |
| Master in Architecture[3] | 63 | 81 | 78 | 191 | 214 | 21 | 648 | 30 | 5 | 13 | 20 | 1 |
| Master of Architecture | - | - | - | - | - | 18 | 18 | - | - | - | - | 18 |
| Master of Architecture in Advanced Studies | - | - | - | - | - | 20 | 20 | - | - | - | - | 20 |
| Master in City Planning | - | 18 | 82 | 114 | 152 | 41 | 407 | 16 | 12 | 20 | 24 | 17 |
| Grand Total | 63 | 259 | 299 | 566 | 577 | 124 | 1,888 | 70 | 37 | 49 | 65 | 59 |

* Includes only February and June degrees.

1 From 1935 to 1944, Bachelor of Architecture in City Planning.

2 Degree of Bachelor in Architecture changed to degree of Master of Architecture in June, 1972.

3 Degree of Master in Architecture changed to degree of Master of Architecture in Advanced Studies in June, 1972.

TABLE XII NUMBER OF DEGREES OF ENGINEER AWARDED

| | Total by decades | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1949-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972* |
| Engineer in Aeronautics and Astronautics[1] | 35 | 58 | 7 | 100 | 6 | 8 | 3 | 4 | 3 |
| Building Engineer[3] | 5 | 2 | - | 7 | - | - | - | - | - |
| Chemical Engineer | 17 | 31 | 11 | 59 | 3 | 2 | 2 | 6 | 5 |
| Civil Engineer | 21 | 78 | 24 | 123 | 9 | 12 | 6 | 7 | 17 |
| Electrical Engineer | 132 | 444 | 92 | 668 | 51 | 61 | 57 | 50 | 42 |
| Marine Mechanical Engineer | 7 | 2 | 1 | 10 | - | - | - | - | 1 |
| Materials Engineer | - | 7 | - | 7 | - | - | - | - | - |
| Mechanical Engineer | 102 | 166 | 26 | 294 | 14 | 16 | 17 | 15 | 11 |
| Metallurgical Engineer | 24 | 18 | 3 | 45 | 3 | 1 | - | 1 | 2 |
| Meteorologist[2] | 2 | - | - | 2 | - | - | - | - | - |
| Naval Architect | 11 | 21 | 3 | 35 | 6 | 2 | 2 | 3 | - |
| Naval Engineer | 334 | 246 | 19 | 599 | 26 | 27 | 27 | 19 | - |
| Nuclear Engineer | - | 37 | 6 | 43 | 3 | 9 | 3 | 4 | 2 |
| Ocean Engineer | - | 4 | 19 | 23 | - | - | 4 | 3 | 16 |
| Sanitary Engineer[3] | 9 | 3 | - | 12 | - | - | - | - | - |
| Total | 699 | 1,117 | 211 | 2,027 | 121 | 136 | 121 | 112 | 99 |
| Awarded jointly with Woods Hole Oceanographic Institution | | | | | | | | | |
| Ocean Engineer | - | - | 3 | 3 | - | - | - | 1 | 2 |
| Grand Total | 699 | 1,117 | 214 | 2,030 | 121 | 136 | 121 | 113 | 101 |

* Includes only February and June degrees.

1 Prior to 1960 Aeronautical Engineer.

2 Degree discontinued after July, 1955.

3 Degrees discontinued after 1964.

TABLE XIII NUMBER OF DEGREES OF DOCTOR OF PHILOSOPHY AWARDED

| | Total by decades | | | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1907-10 | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972* |
| SCHOOL OF ARCHITECTURE AND PLANNING | | | | | | | | | | | | | | |
| Urban Studies and Planning[6] | - | - | - | - | - | - | 24 | 8 | 32 | 1 | 8 | 4 | 3 | 5 |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | | |
| Aeronautics and Astronautics[7] | - | - | - | - | - | 6 | 57 | 16 | 79 | 10 | 7 | 11 | 9 | 7 |
| Chemical Engineering | - | - | - | - | - | - | 31 | 7 | 38 | 2 | 4 | 5 | 6 | 1 |
| Civil Engineering | - | - | - | - | - | 1 | 72 | 21 | 94 | 13 | 12 | 25 | 14 | 7 |
| Electrical Engineering | - | - | - | - | 1 | 9 | 248 | 70 | 328 | 31 | 38 | 39 | 49 | 21 |
| Mechanical Engineering | - | - | - | - | - | 4 | 95 | 31 | 130 | 13 | 16 | 11 | 18 | 13 |
| Metallurgy and Materials Science[3] | - | - | - | - | - | 6 | 103 | 31 | 140 | 14 | 28 | 16 | 24 | 7 |
| Nuclear Engineering | - | - | - | - | - | 5 | 90 | 15 | 110 | 12 | 11 | 11 | 8 | 7 |
| Ocean Engineering[8] | - | - | - | - | - | - | 15 | 6 | 21 | 3 | 1 | 6 | 3 | 2 |
| Sanitary Engineering | - | - | - | - | - | 2 | 3 | - | 5 | - | - | - | - | - |
| Total | - | - | - | - | 1 | 33 | 714 | 196 | 944 | 98 | 117 | 124 | 131 | 65 |
| SCHOOL OF HUMANITIES AND SOCIAL SCIENCE | | | | | | | | | | | | | | |
| Economics[1] | - | - | - | - | 19 | 96 | 195 | 29 | 339 | 20 | 23 | 29 | 18 | 11 |
| Group Psychology | - | - | - | - | 8 | 1 | - | - | 9 | - | - | - | - | - |
| Linguistics | - | - | - | - | - | - | 35 | 8 | 43 | 4 | 6 | 7 | 5 | 3 |
| Philosophy | - | - | - | - | - | - | 8 | 3 | 11 | - | 2 | 2 | 1 | 2 |
| Political Science | - | - | - | - | - | - | 71 | 17 | 88 | 12 | 10 | 11 | 12 | 5 |
| Psychology | - | - | - | - | - | 3† | 24 | 4 | 31 | 2 | 5 | 7 | 2 | 2 |
| Total | - | - | - | - | 27 | 100 | 333 | 61 | 521 | 38 | 46 | 56 | 38 | 23 |
| ALFRED P. SLOAN SCHOOL OF MANAGEMENT | | | | | | | | | | | | | | |
| Management[2] | - | - | - | - | - | - | 89 | 15 | 104 | 13 | 21 | 13 | 9 | 6 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | | |
| Biology | - | 1 | 10 | 17 | 21 | 38 | 105 | 38 | 230 | 12 | 19 | 11 | 17 | 21 |
| Chemistry | 7 | 19 | 59 | 146 | 180 | 342 | 427 | 88 | 1,268 | 40 | 60 | 50 | 58 | 30 |
| Earth and Planetary Sciences[4] | 1 | 7 | 10 | 22 | 20 | 71 | 84 | 14 | 229 | 7 | 10 | 9 | 11 | 3 |
| Mathematics | - | - | 6 | 25 | 35 | 70 | 211 | 40 | 387 | 24 | 18 | 27 | 25 | 15 |
| Meteorology | - | - | - | - | - | 14 | 45 | 10 | 69 | 4 | 10 | 9 | 7 | 3 |
| Nutrition and Food Science | - | - | - | - | 4 | 28 | 66 | 12 | 110 | 12 | 7 | 11 | 9 | 3 |
| Oceanography[5] | - | - | - | - | - | - | 11 | - | 11 | - | - | - | - | - |
| Physics | - | 2 | 6 | 48 | 159 | 283 | 390 | 81 | 969 | 38 | 46 | 48 | 54 | 27 |
| Total | 8 | 29 | 91 | 258 | 419 | 846 | 1,339 | 283 | 3,273 | 137 | 170 | 165 | 181 | 102 |

Table XIII continued

| | Total by decades | | | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1907-10 | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972* |
| AWARDED JOINTLY WITH WOODS HOLE OCEANOGRAPHIC INSTITUTION | | | | | | | | | | | | | | |
| Earth and Planetary Sciences | - | - | - | - | - | - | 4 | 2 | 6 | - | 1 | 3 | - | 2 |
| Meteorology | - | - | - | - | - | - | 1 | 6 | 7 | - | - | 1 | 4 | 2 |
| Grand Total | 8 | 29 | 91 | 258 | 447 | 979 | 2,504 | 571 | 4,887 | 290 | 363 | 366 | 366 | 205 |

* Includes only February and June degrees.

† Previously included in Industrial Economics.

1 Changed from Industrial Economics to Economics 1966.

2 Changed from Industrial Management to Management, February, 1967.

3 Includes Ceramics.

4 Changed from Geology and Geophysics to Earth and Planetary Sciences 1970.

5 Beginning 1967-68 included in Earth and Planetary Sciences or Meteorology.

6 Changed from City and Regional Planning to Urban Studies and Planning, September, 1969.

7 Prior to 1960 Aeronautical Engineering.

8 Changed from Naval Architecture and Marine Engineering to Ocean Engineering, September, 1971.

TABLE XIV NUMBER OF DEGREES OF DOCTOR OF SCIENCE AWARDED

| | Total by decades | | | | | | | | Calendar year since 1968 (included in decade total) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1911-20 | 1921-30 | 1931-40 | 1941-50 | 1951-60 | 1961-70 | 1971- | Grand Total | 1968 | 1969 | 1970 | 1971 | 1972* |
| SCHOOL OF ENGINEERING | | | | | | | | | | | | | |
| Aeronautics and Astronautics[1] | 2 | 4 | 5 | 18 | 31 | 76 | 11 | 147 | 9 | 5 | 9 | 5 | 6 |
| Chemical Engineering | - | 23 | 78 | 114 | 117 | 151 | 14 | 497 | 7 | 12 | 13 | 10 | 4 |
| Civil Engineering | - | 2 | 12 | 23 | 46 | 75 | 12 | 170 | 6 | 4 | 7 | 8 | 4 |
| Electrical Engineering | 3 | 12 | 30 | 34 | 141 | 124 | 14 | 358 | 8 | 4 | 9 | 6 | 8 |
| Electrochemical Engineering | - | 1 | 1 | - | - | - | - | 2 | - | - | - | - | - |
| Mechanical Engineering | - | 4 | 13 | 35 | 125 | 145 | 17 | 339 | 15 | 21 | 4 | 8 | 9 |
| Metallurgy and Materials Science[2] | - | 14 | 32 | 86 | 194 | 201 | 16 | 543 | 11 | 12 | 10 | 9 | 7 |
| Mineral Engineering | 1 | - | 4 | - | - | - | - | 5 | - | - | - | - | - |
| Nuclear Engineering | - | - | - | - | 9 | 55 | 14 | 78 | 3 | 5 | 10 | 4 | 10 |
| Ocean Engineering[5] | - | 1 | - | - | 2 | 6 | 4 | 13 | - | 1 | - | 2 | 2 |
| Petroleum Engineering | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - |
| Sanitary Engineering | - | - | 2 | 3 | 18 | 2 | - | 25 | - | - | - | - | - |
| Total | 6 | 61 | 178 | 313 | 683 | 835 | 102 | 2,178 | 59 | 64 | 62 | 52 | 50 |
| SCHOOL OF SCIENCE | | | | | | | | | | | | | |
| Biology | - | - | - | - | - | 1 | - | 1 | - | 1 | - | - | - |
| Chemistry | - | 2 | 5 | 4 | 3 | 1 | 1 | 16 | - | - | 1 | 1 | - |
| Earth and Planetary Sciences[3] | 1 | 2 | 4 | 5 | 2 | 3 | 1 | 18 | - | - | 2 | - | 1 |
| Mathematics | - | 2 | 3 | - | 1 | 1 | 2 | 9 | - | - | - | 1 | 1 |
| Meteorology | - | - | 6 | 25 | 17 | 6 | 1 | 55 | 1 | - | 3 | - | 1 |
| Nutrition and Food Science | - | - | - | 3 | 10 | 17 | 7 | 37 | 2 | 2 | 2 | 5 | 2 |
| Oceanography[4] | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - |
| Physics | - | 5 | 18 | 14 | 7 | 6 | 2 | 52 | - | - | - | 2 | - |
| Total | 1 | 11 | 36 | 51 | 40 | 36 | 14 | 189 | 3 | 3 | 8 | 9 | 5 |
| AWARDED JOINTLY WITH WOODS HOLE OCEANOGRAPHIC INSTITUTION | | | | | | | | | | | | | |
| Meteorology | - | - | - | - | - | - | 2 | 2 | - | - | - | 1 | 1 |
| Grand Total | 7 | 72 | 214 | 364 | 723 | 871 | 118 | 2,369 | 62 | 67 | 70 | 62 | 56 |

* Includes only February and June degrees.

1 Prior to 1960 Aeronautical Engineering.

2 Including Ceramics.

3 Changed from Geology and Geophysics to Earth and Planetary Sciences 1970.

4 Beginning 1967-68 included in Earth and Planetary Sciences or Meteorology.

5 Changed from Naval Architecture and Marine Engineering to Ocean Engineering, September, 1971.

TABLE XV SUMMARY OF DEGREES AWARDED
(1868 - 1972)

| | |
|---|---|
| Bachelor of Science | 41,600 |
| Bachelor in Architecture | 764 |
| Bachelor in City Planning (discontinued after 1954)* | 31 |
| Master of Science | 20,586 |
| Master in Architecture | 648 |
| Master of Architecture | 18 |
| Master of Architecture in Advanced Studies | 20 |
| Master in City Planning | 407 |
| Master in Public Health (discontinued after 1944)* | 104 |
| Advanced Engineering | 2,207 |
| Advanced Engineering awarded jointly with Woods Hole Oceanographic Institution | 3 |
| Doctor of Philosophy | 4,874 |
| Doctor of Philosophy awarded jointly with Woods Hole Oceanographic Institution | 13 |
| Doctor of Science | 2,367 |
| Doctor of Science awarded jointly with Woods Hole Oceanographic Institution | 2 |
| Doctor of Public Health (discontinued after 1944)* | 9 |
| Doctor of Engineering (discontinued after 1918)* | 4 |
| Grand Total | 73,477 |

* See 1959 Report of the Registrar for details.

WARREN D. WELLS

# Vice President and Secretary of the Institute

The assignment of the Vice President and Secretary of the Institute is to provide staff support to the Corporation and the Committees of the Corporation, to coordinate the Institute's relations with industry, and to supervise the ongoing program to develop private support for M. I. T. The past year brought significant changes in many of these areas, due both to the change of Administration at M. I. T. and to external factors. The $22 million total of gifts, grants, and bequests received during the year represented the sixth highest total for any year since the founding of the Institute. With the exception of a bequest payment which made last year's gift income a near record, this year's overall gift experience represented an improvement over last year of about $1 million.

The directors of the Industrial Liaison Office, M. I. T. Associates Office, Registry of Guests, and Development Office and the Manager of Endicott House have submitted reports to the President which are part of the formal record of the Institute. This report summarizes their work and the progress of the Institute Secretaries, who also report to the President through the Vice President and Secretary of the Institute. Additional short-term responsibilities assumed by the Vice President and Secretary during the past year included the secretaryship of the Executive Committee of the Corporation for the summer of 1971 and the planning of arrangements for the Inauguration of President Jerome B. Wiesner and Chancellor Paul E. Gray.

## Corporation Membership

At the year's end there were 86 Members of the Corporation - 75 Active Members, 10 Life Members Emeriti, and 1 Member-Elect of the Corporation due to assume office at the Meeting of the Corporation on October 6, 1972, as a Representative from Recent Classes. During the year the Corporation regained through election at the Annual Meeting on October 8, 1971, the membership of J. Kenneth Jamieson, '31, Chairman of Standard Oil Company of New Jersey, for a second five-year term. Five new Representatives from Recent Classes also took office as Members of the Corporation at the Annual Meeting.

The Corporation lost through death on April 29, 1972, Life Member Emeritus, Duncan R. Linsley, '22, former Vice Chairman of The First Boston Corporation, and on May 17, 1972, its Life Member, William Webster, former Chairman and President of New England Electric System.

After four years in office, Dr. Neil V. Sullivan announced his resignation as Commissioner of Education of the Commonwealth of Massachusetts shortly after the year's end. In this capacity he also served as one of three ex officio Representatives of the Commonwealth on the M. I. T. Corporation. At this writing, the Commonwealth has not announced Dr. Sullivan's successor.

At the Meeting on June 2, 1972, the Corporation elected the following to five-year terms: W. Gerald Austen, '51, Chief of Surgery, Massachusetts General Hospital; W. Van Alan Clark, Jr., '42, Chairman of the Board, Sippican Corporation; Rebecca A. Donnellan, '71,

Student, Harvard Law School; W. H. Krome George, '40, President, Aluminum Company of America; Paul V. Keyser, '29, Former Executive Vice-President and Director, Mobil Oil Corporation; Ralph Landau, '41, President, Halcon International, Inc.; Clint W. Murchison, Jr., '44, Partner, Murchison Brothers; I. M. Pei, '40, Principal, I. M. Pei & Associates; and Paul P. Shepherd, '53, Senior Vice President of Engineering, Cabot, Cabot & Forbes, Inc. Our Member, Breene M. Kerr, '51, Principal of Resources Analysis and Management Group, Inc., assumed the additional position as ex officio Member of the Corporation by virtue of his election as the 1972-73 President of the Alumni Association.

Expiration of term membership has cost the Corporation the formal services of Albert H. Bowker, '41, Chancellor, University of California at Berkeley; George P. Edmonds, '26, Honorary Chairman, Wilmington Trust Company; Ralph F. Gow, '25, Former President, Norton Company; Donald A. Holden, '31, Executive Director, Council of Independent Colleges in Virginia; H. I. Romnes, Former Chairman of the Board and President, American Telephone and Telegraph Company; and Laurence Storch, '71, Student, Harvard Law School. These retiring Corporation Members continue their association with the Corporation in important ways as members of various Corporation Committees.

As a matter of record, the Corporation held four meetings during the year. In a year when the new leadership of M. I. T. demanded an extra effort by all segments of the Institute community, the Corporation played a central role in communicating with students, faculty, alumni, and general public on the range of questions and issues before M. I. T. Special thanks are due the Ad Hoc Committee on Shareholder Responsibility, under the chairmanship of Jeptha H. Wade, and C. J. A. C., under the chairmanship of James A. Champy, for their invaluable assistance to the Executive Committee and to the Corporation respectively. Walter L. Milne, Assistant to the Chairman of the Corporation, served as Secretary to the Committee on Shareholder Responsibility. Additional thanks are due the Corporation Screening Committee, under the chairmanship of Ralph M. Davison, and the staff of the Alumni Association for the devoted effort required to conduct the special alumni election needed to fill a vacancy in the membership category, Representatives from Recent Classes.

## Corporation Joint Advisory Committee on Institute-wide Affairs

This new advisory committee to the Corporation completed its third year of operation and its first year under the chairmanship of James A. Champy, '63. The Committee held 14 regular open meetings during the year, as well as three closed meetings; these included sessions with the President, Members of the Corporation, and various officers of administration. Special attention was given by C. J. A. C. to issues involved in equal employment opportunity, employee development, and housing for residents of Cambridge. Other important topics examined by C. J. A. C. included a continuing study of the plans for the development of the Simplex property near M. I. T., the issues involved in shareholder responsibility, and the finances of M. I. T. The writer wishes to acknowledge once again the remarkable contribution C. J. A. C. has made on these and other questions in building respect and mutual understanding within the M. I. T. community. Particular credit is due the chairman, James A. Champy, for his skillful and stimulating leadership of C. J. A. C. The Committee was assisted in its deliberations by the able staff support of Robert D. Blake and his office. The undersigned also wishes to express appreciation to Gregory Smith, '30, who served as a Corporation Member on C. J. A. C. who voluntarily transcribed the tapes of a large fraction of the C. J. A. C. meetings and who played an active role in C. J. A. C. deliberations.

## Dedications

The Office of the Vice President and Secretary continued to carry prime responsibility for dedications of major facilities. Notable ceremonies this year included the dedication of the George R. Wallace, Jr. Astrophysical Observatory near the site of the Haystack Radar Facility of Lincoln Laboratory in Westford, Massachusetts; the opening of the J. B. Carr Indoor Tennis Center; and the naming of William H. Bates Linear Accelerator of the Laboratory for Nuclear Science in Middleton, Massachusetts. The arrangements for the inaugural events period and a number of departmental functions were planned and executed with assistance from the Office of the Vice President and Secretary. Notable among these was an open house in the newly renovated Eastman Building of the Department of Chemistry.

The Vice President and Secretary wishes to acknowledge the heroic assistance of Paul E. Johnson and Alice Tripp, both of the Office of Institute Information Services, in the handling of the Wallace and Bates dedications and in the key roles they played in the inaugural events period.

## Corporation Visiting Committees

The expansion in size of each Visiting Committee was continued in 1971-72, looking toward an ultimate composition of three Corporation nominees, six presidential nominees, and six alumni nominees -- or 15-member Committees in place of the previous nine-member Committees. The rationale for this move is to strengthen the Visiting Committees, to recognize the growing numbers of distinguished alumni who are eligible and anxious to serve on these Committees, and to support greater attendance at mid-winter meetings of Visiting Committees. The expansion process was begun two years ago. With one exception, all of the Visiting Committees now have 14 or more members and 19 Committees have the full complement of 15 members.

In 1971-72, 381 individuals served on one or more of the 28 Visiting Committees. They included 59 Members of the Corporation, 174 Members nominated by the President, and 147 Members nominated by the Alumni Association. The outlook for 1972-73 is for the completion of additional recruitment of Visiting Committee Members to provide a total of some 400 advisors serving the Institute in these key Committees.

Corporation Members chair and typically serve on two Visiting Committees; although they are appointed from year to year, their tour of duty on a given committee is roughly twice as long as the other nominees on the Committee. The recruitment of Committee members results in a wide distribution of professional backgrounds. Fifty percent of the total Visiting Committee members are from industry, 27 percent from education, 9 percent from government, 4 percent from financial institutions, and the remaining 10 percent are drawn from other sources or are simply highly qualified individuals who bring a personal point of view to the Committee deliberations. Interestingly, 22 percent have held previous staff appointments at M. I. T.

During the year, a record number of 24 Visiting Committees held meetings, not including the Visiting Committee for the Harvard-M. I. T. Joint Center for Urban Studies. Seventeen of the Committees which met held dinner meetings prior to the day of their formal sessions, with very great effectiveness. The number of Committees which met was somewhat greater than the optimum number and too many of the meetings were bunched once again in the spring of the year, with a punishing crush on the calendar. Three-fourths of the meetings were held in March, April, and May of 1972. With the earlier fall term beginning in September and the Independent Activities Period in January, the Corporation is endeavoring to place as many of these meetings as possible in the fall

term of the 1972-73 year, despite the inherent problems in doing this. Although the Visiting Committees are not constituted officially until October of each year, the Corporation has reached the conclusion that it will be necessary to elect the Chairmen in the preceding spring of each year and to try a moratorium on meetings after May 1 of each year.

David J. Tobin provided administrative support to the Visiting Committee program, including the scheduling and arranging of meetings, sending pertinent reports and press notices to the Committees during the year, processing the written reports of Committee meetings and, in general, providing a base for effective communication with the individual Visiting Committee Members. Thanks are due once again to President Wiesner, Chancellor Gray, and Provost Rosenblith and to the Nominating Committee of the Alumni Association for their help in the selection of nominees to these important Committees of the Corporation. Dr. Rosenblith was an active participant in Visiting Committee meetings, along with the deans, and he was a principal representative of the President and Chancellor in those parts of meetings they could not attend. The writer also wishes to acknowledge and thank the department chairmen for their excellent preparation for Visiting Committee meetings and the enthusiastic participation of well over 300 faculty members in these sessions.

The inclusion of student meetings, presentations, and discussions in the regular agenda of these Visiting Committee meetings was a major factor in the success of the Visiting Committee operation this year. The Committee chairmen made a concerted effort across the board to include extensive contact with students in each of the departments and areas being visited. At the request of one Corporation Member, the Committee chairmen also made an across-the-board effort to inquire into the departmental progress of minority recruitment of students and faculty. It is worth repeating that it is the Institute's great good fortune to have this system of advisory committees during a period when students have sought a greater voice in the governance of the Institute and when opportunities for student-trustee interaction are a priceless asset in the process of change. Within the context of departmental and professional concerns, M. I. T. students, and those from other institutions who have served as Committee members from time to time, have brought invaluable experience and perspectives to bear on the deliberations of the Visiting Committees. At the invitation of the American Chemical Society, the undersigned presented a paper summarizing the Institute's 40 years of experience with the Corporation Visiting Committees.

## Development

As reported earlier, the cash total of over $22 million in gifts, grants, and bequests was the sixth best year for private support since the founding of the Institute. It was the Institute's second best year of cash support from donors in the last five years -- excluding receipts from bequests. The past year was particularly noteworthy because of the solid progress made within the several components which make up the grand total of gifts, grants, and bequests; several new records were set.

This progress is worth analyzing because it represents the result of a conscious decision to carry forward the Institute's plan, in effect since 1963, to conduct a continuous, intensive search for capital funds, project by project, under the leadership of the Corporation Development Committee instead of conducting a massive, highly publicized capital campaign. The year's progress in development also represents an optimistic and hopeful outlook for future private support of M. I. T., as the Institute continued to broaden the base of its donors and overall gift support. The year produced a six-year record in the number of gifts from all sources which were in excess of $100,000 each. Regardless of how well this mode of fund raising has served the Institute over the past decade, it remains to be seen whether it can keep pace with the evolving capital

requirements of M. I. T., especially in the growth of endowment needed to correct M. I. T. 's gross undercapitalization.

## The Need for Endowment

It is not enough to speak of steady progress in gift income without paying special attention to M. I. T. 's continuing dilemma of undercapitalization. Every School and academic department at M. I. T. is affected. With a ratio of total invested funds to annual operating expense of about 3.5, the Institute stands well behind its peer group of U. S. colleges and universities in endowment strength. It would take an immediate infusion of at least $100 to $150 million of permanent endowment, holding expenses constant, to put M. I. T. on an equal endowment footing with institutions of comparable quality -- to say nothing about what would be needed to turn M. I. T. 's balance sheet into Camelot.

Some 1971 comparisons are possible with data derived from recently published figures by the Council for Financial Aid to Education (CFAE). In 1971, there were 34 private colleges and universities in the United States with total invested funds of more than $50 million each, at market value. Relative to their annual operating expenses, these private institutions were in various states of well-being as measured by the ratios of their total invested funds to total operating expense.

Some of the leaders and their invested funds/operating expense ratios were:

| | |
|---|---|
| 7 | Princeton University |
| 6 | Harvard University |
| 6 | Rochester University |
| 5 | Dartmouth College |
| 5 | Yale University |

Data on Columbia University was not reported. Interestingly, M. I. T. 's ratio of 3. 5 was similar to that of California Institute of Technology and Rensselaer Polytechnic Institute but it was, and is, clearly out of line with M. I. T. 's place in American higher education and not at all in keeping with M. I. T. 's responsibilities as a world leader in scientifically based education. On a per-student basis, M. I. T. 's invested funds also place the Institute behind many of the leaders with whom the Institute competes for high-talent students.

Although M. I. T. 's total invested funds, as reported by CFAE in 1971, stood at $404 million and represented the fourth largest private endowment in the country -- after Harvard ($1, 093 million), Yale ($547 million), and Rochester ($407 million) -- the Institute had to rely, as it has during the entire post-World War II period, on a much greater fraction of year-to-year funding for its annual budget than did all of these institutions.

It should be remembered that all of these institutions are straining to maintain their financial integrity during the deepest depression in American higher education since the 1930s. They are all needy, some more than others. Furthermore, these ratios are misleading in the sense that the restrictions surrounding most collegiate endowments, including M. I. T. 's, do not allow the degree of managerial flexibility that every college president needs to meet changing conditions and priorities. However, the invested funds/operating expense ratios do indicate, if only in a crude way, the relative financial strength of some of the premium private institutions in this country. Even the best-endowed private and public universities live under strained financial conditions; those with little or no endowments live in the constant shadow of insolvency.

The use of temporary, short-term funds is always risky. In times of depression, it is all the more hazardous, as many private institutions are painfully learning. For example, New York University's highly publicized budgetary problems are compounded by the fact

that N. Y. U. 's annual budget is larger than the total market value of its invested funds - a ratio of 0.5 in the comparisons made earlier.

In the short term these conditions place a premium on M. I. T. 's ability to generate new sources of unrestricted funds along with continued strong budgetary control. In the longer term, an adequate endowment is the only sure way to provide the financial base needed for M. I. T. 's orderly development. This is not an idle plea for more funds to dress up the Institute's yearly gift income; it is fundamental to M. I. T. 's future.

M. I. T. has been more fortunate in one important respect than many other institutions with better endowments. While the Institute has not been able to improve its endowment position relative to its annual operations, by strenuous effort on the budgetary, fund raising, tuition and investment fronts it has also not lost ground significantly - as have most of the endowment leaders. However, in order to produce a balanced budget, M. I. T. has now exhausted its unrestricted resources and has had to forego the normal, annual buildup of reserves - both of which have traditionally been more important to M. I. T. than to many institutions because of the Institute's heavy reliance on short-term sources of funds.

These delicate balances between the present and the future would be relatively easy to determine were the choices based solely on financial considerations. They obviously are not. The expenditures made in any given operating year are only partially related to present operating considerations; much of what is called operating expense is in itself an investment in M. I. T. 's future development of students, faculty, and academic program. Thus, an analysis which compares investments with operating expense suffers from sterile thinking on educational grounds. Yet the buildup of capital needed for the production of future educational income is a necessary and inescapable, even though it can never be sufficient, guarantee of educational quality.

M. I. T. 's strained finances are threatened further by prospective losses of operating revenue to the general account from the separation of the Charles Stark Draper Laboratory from the Institute, now planned for June 30, 1973. The urgency of this aspect of M. I. T. 's finances is such that a number of capital projects have had to be deferred in favor of concentrating on the core needs of the Institute.

## Highlights of the Year

During 1971-72, a determined effort was made to identify new sources of support to increase the Institute's unrestricted resources and for student aid, educational innovation, faculty endowment, the completion of building projects to which the Institute was already committed and for which partial funding had already been secured - such as the Electrical Engineering and Electronics Complex and the private portion of the funding for Westgate II- and the launching of a $12.1 million drive for new facilities for Chemical Engineering.

The Corporation Development Committee (C. D. C. ), under the brilliant Chairmanship of Dr. Killian, once again provided leadership in the acquisition of capital resources. The Committee held its annual meeting in Cambridge on October 7, 1971, in conjunction with the Annual Meeting of the Corporation and the Inauguration the following day. During the year, President Wiesner and Chancellor Gray visited with many C. D. C. members in their home cities, as did Dr. Killian and the development staff. Dr. Gray was guest of several luncheons in major cities given by Development Committee Members.

Members were asked on an individual basis to continue their efforts to assist M. I. T. in securing a minimum of $100,000 each in new funds, as part of the problem of dealing with uncompleted capital projects and the need for additional unrestricted funds. The results were most gratifying, with new Committee members contributing ideas, information, and

in many cases personal introductions and gifts to help meet the Institute's request. This important, new phase of Committee work is continuing.

The addition of new members to the Development Committee increased its strength to 142, including 25 Members of the Corporation and 117 alumni serving for three-year terms. There are 10 new alumni members. The Committee lost through deaths the devoted services of Henri P. Junod of Cleveland, William L. Abramowitz of Boston, and William C. Mentzer of San Francisco.

Thanks are due Donald P. Severance and Kenneth S. Brock of the Alumni Association and to Nelson C. Lees and James W. Lambert and Donna M. White, who served as secretary in the Development Office, for their assistance in maintaining the quality of this key Committee. Elizabeth A. Pigott served as Administrative Assistant for the Committee and provided her usual, first-rate support for its Chairman.

Space does not permit a full discussion of all of the encouraging achievements of 1971-72 but a few of the noteworthy items follow:

First: Dr. Howard W. Johnson established an internal Council on the Resources of the Institute to meet regularly to review the development priorities of the Institute. The Chairman, President, Chancellor, Chairman of the Development Committee, Vice President and Treasurer, and Vice President and Secretary constitute this Council.

Second: President Wiesner organized a nationally based Council for the Arts at M. I. T. under the chairmanship of Paul Tishman, '24, of New York City. Angus N. MacDonald, '46, and Ida Rubin were named Vice Chairmen of this advisory group to the President. Some 35 members have been recruited, representing a national constituency of persons interested in fostering the development of the Arts at M. I. T. Catherine Stratton served as Secretary of this new Council during the year. Professor Roy Lamson of the Department of Humanities was appointed Special Assistant to the President to help organize faculty support for this new Council. Karen Mathiasen was appointed Administrative Officer to provide staff support to the Council.

Third: The Institute had an active year in organizing sponsoring groups for high priority projects. A National Sponsoring Committee to secure funds for the joint Harvard-M. I. T. Program in Health Sciences and Technology was organized under the Co-Chairmanship of Charles F. Adams and Dr. George W. Thorn; the Committee held its first meeting at the M. I. T. President's House on March 13, 1972, to begin its initial drive for $10 million in endowment funds for the Joint Program. A second National Sponsoring Committee for the drive to secure funds for the new Chemical Engineering Building was organized under the chairmanship of J. Kenneth Jamieson, '31; this Committee, led by Mr. Jamieson and Dr. Howard W. Johnson, held its first session at M. I. T. on March 10, 1972, and had raised $4 million in corporate and individual pledges by June 30, 1972, towards a $12.1 million goal. A third National Sponsoring Committee of food industry executives was instrumental in helping the Institute to complete the initial endowment of $600,000 to launch the Underwood-Prescott Professorship of Food Science - the nation's first fully endowed chair in Food Science. President Wiesner announced the completion of the minimum endowment for the Professorship and the appointment of Dr. Samuel A. Goldblith as the first incumbent at the 150th anniversary of the U. S. canning industry on May 25, 1972, at a Boston meeting of the National Canners Association.

Fourth: There was a net addition of 16 living individuals whose personal donations and new pledges brought the total of living donors who have given M. I. T. $25,000 or more during their lifetime to 217 living individuals.

Fifth: The dollar total of gifts by living individuals, though down about 10 percent from last year's total of $5.3 million, continued to grow significantly in the middle and lower ranges of giving. Gifts by individuals continue to represent M.I.T.'s great hope for increased total private support for the future. In addition, the number of living donors reached a new high for a single year. The donor count was helped by the continued steady increase of Alumni Fund donors to a record of over 22,000 - an increase of 4 percent in donors to the Fund. M.I.T.'s improved Alumni Fund experience was consistent with the improved performance of the leading annual funds of sister institutions, both in percent participation and dollars contributed, according to Kenneth S. Brock, '48, Director of the Fund. In addition to the Fund's steady improvement, a number of Reunion Class Gifts set new records for Class contributions over the past five years.

Sixth: The number of plans for estate gifts on record with the Institute Estate Secretary has increased by a record net of 120 persons, after a careful review of existing donor intentions. A record total of 825 individuals, both alumni and friends, have now notified the Institute of their plans on a confidential basis - up from 705 last year. This total includes 40 life income trusts held by M.I.T. and 25 estates in process. The number of 825 individuals with estate plans on record has grown from 223 in the seven years since July 1, 1965.

Seventh: Gifts and grants by foundations and charitable trusts made a further strong comeback this past year. Foundations, numbering 108, and 13 charitable trusts made gifts and grants totaling $7.0 million - up by $500,000 for the second year in a row. Included were 25 foundations and charitable trusts which made gifts and grants to M.I.T. for the first time. Gifts and grants from foundations other than the Ford Foundation and Sloan Foundation also showed an encouraging increase for the sixth consecutive year. Their dollar total has increased from $3 to $5 million in the past three years. Whereas, Ford and Sloan represented roughly three-fourth's of M.I.T.'s foundation income as late as 1968, the greater growth of other foundation sources has reduced the Ford and Sloan fraction of total foundation giving to M.I.T. to around 30 percent of the total.

The leverage value of modest support from private foundations continues to be greatly underestimated. When the modern history of M.I.T. is written, it will be seen that private foundations and trusts played a decisive role in launching new programs.

The Institute's ability to attract foundation support from a broader base of philanthropic institutions reflects a partial shift from Federal to private funding of research and teaching at M.I.T., the beginning of a higher national level of foundation payouts, and a persistent effort by the Institute Secretary for Foundations and the Institute Secretary for Charitable Trusts to develop greater effectiveness in M.I.T. appeals to foundation sponsors. Thanks are due the Office of the Provost for a banner year and strong faculty participation in foundation appeals.

The full effects upon foundations from the Tax Reform Act of 1969 are now fairly clear. There does not appear to be a wholesale movement to abandon existing private foundations as had earlier been feared, although there have been isolated cases of foundations electing to discontinue operations.

Eighth: Corporate gifts and grants continued their remarkable upward climb with the return to more favorable corporate earnings. With the exception of grant payments from one major corporate donor, industrial support reached a six year high of $6.5 million. This represented nearly 30 percent of M.I.T.'s total income from gifts, grants, and bequests and served to emphasize once again the Institute's very great dependence upon support from American industry. Whereas M.I.T. relies upon corporate sources for between 20 percent to 25 percent of its total gift income, the comparable figure of U. S. colleges and universities, on the national average, is about 14 percent.

Ninth: An important start was made during the year to begin the articulation of venture capital giving as a wholly new source of potential income for M. I. T. The M. I. T. Development Foundation, Inc., a non-profit corporation managed by M. I. T. for the benefit of M. I. T., was established to attract founder stock gifts and to assist would-be entrepreneurs at M. I. T. in developing ideas to the point at which technological transfer to industry can take place more expeditiously. Richard S. Morse of the Alfred P. Sloan School was elected President of this new entity, reporting initially to Vice President Albert G. Hill and later to an independent board, of which Dr. Hill serves as Chairman.

Tenth: The number of off-campus visits paid to donors and prospective donors by members of the faculty and development staffs, including the visits paid under the Industrial Liaison Program exceeded 1,000 for the second year. The intensified search for private support, under the Institute's new Administration has led to greatly increased contact with industry and private sources of philanthropy.

### Staff

The Institute Secretaries—D. Hugh Darden, Malcolm G. Kispert, C. Warren Smalzel, David J. Tobin, and Paul H. Burr—and Arnold H. Singal assisting Mr. Darden, set new records in developing improved communication with prospective donors among private individuals, corporations, charitable trusts, and foundations. Mr. Darden was active in clarifying tax matters as they relate to changes imposed by the Tax Reform Act of 1969. These six development officers, working closely with the Development Office, were responsible for the day-to-day performance of a development program that places M. I. T. among the nation's top private universities receiving support—with institutions that are larger and older. M. I. T. is exceptionally fortunate to have these senior administrative officers who are committed to keeping the Institute financially strong and free. Their work was bolstered during the year by the full-time addition of the services of Mr. Kispert, who began a special effort to attract increased financial support for student aid from alumni and friends of the Institute.

If the Institute's development effort works well or works at all, its pulse and its nerve center can be traced to the Office of Development. Under the direction of Nelson C. Lees, this hard-working Office continues to enlarge its responsibilities and strategic services to the Institute. Mr. Lees has noted in his report that the Development Office, once organized to provide services exclusively to the President and Chairman, now serves a wide range of senior officers at M. I. T., as well as a number of branch funding operations at M. I. T. The Development Office is both a research and operations center for development processes that go well beyond the call of ordinary duty to an extraordinary institution. It is an acknowledged professional leader in its field. It underpins M. I. T.'s total development effort with a fraction of the staff of comparable offices in other major universities; it does so because of an abiding sense of mission and esprit among its staff that come from a close coupling to the heart of decision making at the Institute, but it also reflects in everything it does the remarkable personal qualities of its Director. During the year, James W. Lambert was promoted to the well-deserved post of Associate Director, and Karen Mathiasen was appointed to the staff of the Office to provide development and administrative services to the Council for the Arts at M. I. T.

## Federal Legislation

The Higher Education Act of 1972 was passed by Congress and signed into law by President Richard M. Nixon. However, the initial projections of no net immediate gain in operating revenues for M. I. T. now have been confirmed by Secretary Richardson. The Basic Opportunity Grants, which are an important student aid feature of the Act, will not become operative until 1973-74 and then only if funds are appropriated. The same is true of those provisions of the Act relating to direct institutional aid. Regrettably, a

general impression is afoot in the country that the nation has now responded to the financial crisis in higher education. Nothing approaching a solution is embodied in the Higher Education Act. The private sector will have to dig deeply into its own resources if our private institutions are to be kept viable. In M. I. T. 's case, for example, the largest possible dollar total that might eventually come to the Institute, if and when the Higher Education Act is finally funded completely, would be $1. 5 million per year, or a little more than 1 percent of M. I. T. 's current annual on-campus operating budget.

In the meantime, new rumblings were heard in a national election year about proposed Federal income and estate tax reforms that would deal deadly blows to private philanthropy in the United States. Increasing signs now point to a pitched battle that will have to be waged in Congress this coming year to preserve the present tax treatment of charitable remainder trusts and the gift of appreciated property to charitable purposes.

It would be a national tragedy if our public policy, which has sought consistently to encourage private initiatives and a pluralistic system of organization in the area of philanthropy, was to be reversed in favor of the monolith of government finance. No responsible citizen questions the need for tax reform but those who would seek to eliminate tax advantages in giving are clearly endangering the whole system of higher education in this country. The uncertainty factor alone may set back private support for two or three years as it surely did during the period leading up to and following the enactment of the Tax Reform Act of 1969.

At a time when all available top-level help is urgently needed for solicitation of major private support, it is a national loss that college officials will have to turn aside from such work to help defend the present system of tax credits which encourage private philanthropy.

## Industrial Liaison Program

Four new companies joined the Industrial Liaison Program during 1971-72; a fifth has indicated an intent to become a member. The net financial effect of these new corporate members will be to add some $500, 000 to M. I. T. 's unrestricted funds over the next five years. This is one measure of the importance of the Program to M. I. T.

At the close of the fiscal year, membership in the Industrial Liaison Program stood at 90 companies, down about 10 percent, compared with membership levels of the two preceeding years, but greatly improved in quality and interest. The delayed effects of the earlier downturn in the economy and the depression in the aerospace industry are still being felt as three companies did not renew their memberships during 1971-72. Five companies which were unable to make a payment in the preceeding year (1970-71) were reluctantly terminated when no acceptable financial arrangement could be reached during this past year. These actions reflect an increasingly more businesslike approach on M. I. T. 's part to membership status due to pressures resulting from budget reductions and the Institute's great and growing need for unrestricted funds.

It is expected that the upturn in the economy, combined with an intensified solicitation effort, will bring additional organizations into the Program. Among these it is hoped that new ground will be broken through the establishment of formal relationships with selected foundations and governmental agencies which could also benefit from closer ties with the Institute.

During the past year 14 symposia were offered for the benefit of member companies. Total attendance was 1, 440 persons, up significantly from last year's total of 1, 030 when 15 meetings were scheduled. The increase in attendance is attributed to both a relaxation

of travel restrictions by the companies and the excellence and timeliness of the subject matter. Budget restrictions resulted in the slight reduction in the total number of symposia offered and the reduction from three to two in the number of meetings held away from the Institute.

Another record in the number of identified research projects was attained when 1,719 projects were listed in the 1972 Directory of Current Research, an increase of 100 projects over the number listed in the 1971 Directory. A total of 4,905 copies of the Directory were distributed and served as the basis for many of the requests for information processed by the Office.

The total number of requests for publications processed by the individual Industrial Liaison Officers and the I. L. O. Publications Office increased markedly to 6,900 requests from 5,500 requests recorded in the previous year. Much of this increase resulted from a change in distribution procedures put into effect the previous year in an effort to make the publications service more efficient by reducing the number of publications which were automatically distributed. The net effect over the past two years has been a reduction of almost 50 percent in material expenditures in the publications area, while the service has become more personalized.

The staff of the Industrial Liaison Office gratefully acknowledges the support of the M. I. T. Libraries in issuing 507 Privilege Cards to individuals in member companies. This is a service which is greatly appreciated, especially by the local companies and those with specialized library needs.

The opportunity for personal contact with the faculty and staff at the Institute continues to be an essential part of the Program. During the year, 468 representatives from member companies participated with faculty and staff in 709 separate conferences arranged by the Liaison Officers. Additional contact was provided through the 199 visits made by the faculty and staff to member company facilities. A total of 282 separate visits were made by the Liaison Officers to keep abreast of company interests and activities. In the area of undergraduate education, the Industrial Liaison Office provided assistance and advice to the Undergraduate Research Opportunities Program (U. R. O. P. ) in setting up off-campus arrangements for M. I. T. undergraduates to participate in industrial research and development laboratories. The Vice President and Secretary views this development with keen interest and looks forward to its expansion in the year ahead, both as a service to M. I. T. undergraduates and to the member companies.

This past year has also been one of significant change in personnel in the Industrial Liaison Office. Jack W. Christensen, who had been Director of the Industrial Liaison Program for the past four years, left the Office at year's end to join the newly formed M. I. T. Development Foundation, Inc. He was succeeded by Charles J. Sheehan, who had served along with J. Peter Bartl, Ronald A. Norelli, and James E. Fleischhacker as Liaison Officers during the past year. Anne S. Hirsch, the first woman to be appointed an Industrial Liaison Officer, and Dennis C. Jedlinsky joined the staff to replace Jerome J. Schaufeld, who was appointed Director of the M. I. T. Associates Program, and Harry C. Moser who left the Institute to accept a position in industry upon completion of a successful three-year appointment. Elizabeth L. McLean served as Administrative Assistant during the year. No words are adequate to express the monumental contribution Jack Christensen has made to M. I. T. 's relationships with industry during the nine years he served in the Liaison Office, especially in his last four years as Director.

The outlook continues to be highly encouraging for the Industrial Liaison Program. The Institute is pledged to give its best efforts to maintain essential services to the member companies and to seek new opportunities for mutually beneficial exchanges. Interest from

and opportunities by the M. I. T. faculty and staff are at a new high, thanks to the activity of the Faculty Committee on Industrial Liaison and to the natural, professional interest among member companies in taking advantage of the new concern among students and faculty for work in technical areas, once thought to hold less challenge but now regarded as vital to the application of technology to societal problems. Very old fields, like sanitary engineering, have come alive again in modern attire.

In conjunction with the senior officers of the Institute and with C. Warren Smalzel, Institute Secretary for Corporations, the Liaison Office looks to improved business conditions to assist in bringing new companies into the Program. The professional values and the unrestricted income derived from the Program are crucial to M. I. T.'s independence and strength as a privately controlled institution. The example of close cooperation with industry continues to attract attention as an underdeveloped resource in American higher education.

## M.I.T. Associates Program

The M. I. T. Associates Program serves as an interface between the Institute and small to medium-size companies and those with well-defined technological interests in the research under way at M. I. T. Their participation also represents an important source of unrestricted funding to the Institute.

The prime service offered to these companies under the Program is the organized approach to discussions about ongoing research with the Institute faculty and staff. This year saw an increased level of this activity as measured by the number of company visits to the campus. Forty-nine representatives from member companies met with 70 of the M. I. T. faculty and staff.

To enhance this interaction further, a new service was initiated this year. A periodic Round Table meeting is being presented on timely topics that reach from corporate product interests to those of a broader nature. The first meeting was presented this year under the direction of Professor Edward B. Roberts of the Alfred P. Sloan School of Management and was entitled "Corporate Venture Management: Internal vs. External." The format of this meeting was a presentation by Professor Roberts which was followed by informal discussion over lunch. A total of 21 company participants attended this meeting.

Other services such as the issuance of library cards to member companies, distribution of publications, and attendance at M. I. T. colloquia and seminars continued at a high level during this year. As in the case of the Industrial Liaison Program, the Vice President and Secretary looks forward to the growth in membership of this Program; at year's end there were 24 companies participating.

As in previous years, the Associates Office, then under the energetic direction of Leslie M. Boring, Jr., organized and executed the Institute's annual New England Executives Conference. At the Conference a record 349 participants attended a series of five panel workshops which convened on the following topics of particular interest to New England businessmen: International Business; Energy Resources; Human Resources and Skills; The Management of Innovation; and New England Finance and Investment Decisions. At the dinner following the day's activities, Professor Lucian W. Pye, Professor of Political Science at M. I. T., spoke of China and the Politics of Foreign Investment in the Far East. The Conference, like its predecessors, provided an excellent forum for the exchange of information and ideas among New England executives and the M. I. T. faculty and staff.

Midway during the year, Jerome J. Schaufeld was appointed to the position of Director of the M. I. T. Associates Office from the staff of the Industrial Liaison Office. He succeeded Leslie M. Boring, Jr., who resigned to accept another post at M. I. T. The Vice President and Secretary wishes to thank both men for their creative efforts to develop the Associates Program, especially for their successes.

## Registry of Guests

The Registry of Guests, under the devoted and able direction of Carolyn B. Cox, logged a total of 1,150 visitors from 73 countries during the year, an increase of about 10 per-cent. This year France topped the list with 128 short-term visitors, displacing Japan which has consistently led the list in recent years.

The number of foreign staff and faculty recorded by the Registry was slightly higher than in preceding years with a total of 515 long-term visitors. Again this year the largest proportion was from England, and in all 53 countries were represented.

The Registry is grateful for the generous assistance given by Eugene R. Chamberlain and Robert A. Schuiteman of the Admissions Office, as well as for the willingness of faculty and staff to join in extending courtesies and visit privileges to foreign visitors. Without this strong help the steady increase of administrative workload required to handle visas, visitor orientation, and protocol connected with the Immigration Act of 1965 could not go forward.

Mrs. Cox reports that a considerable amount of Registry time was expended as usual in preparing for Commencement. She also contributed importantly to the work of the Inaugural Events Committee. With the current trend toward more informal inauguration ceremonies, however, there was less need to invite delegates to represent M. I. T. at academic functions at other institutions, but there was still demand for a number of formal Institute Greetings to be prepared by the Registry.

The Institute has the great good fortune to have the direction of the Registry in Mrs. Cox's hands. She has managed so well that few have noticed the substantial growth in volume and complexity of work done by the Registry. Through it all, she has somehow managed to keep her wit, charm, and spirit that have come to be associated the world over with the rendering of first-rate hospitality at M. I. T.

## M.I.T. Endicott House

Continued capital improvements to M. I. T. 's conference center in Dedham, Massachusetts, income improvements under a new rate structure and cancellation policy authorized by the Endicott House Board of Governors, and the beneficial effects of a clarification of use policy for the House were among the significant developments during the year.

An important reason for the greatly improved financial result this year is the fact that Endicott House remained open the full 12 months. It continued to play a key role in expanding educational opportunities for the departments and laboratories of the Institute. The Alfred P. Sloan School of Management continued as the heaviest user of the House, with two sessions of the Program for Senior Executives and a special Program for Urban Managers. In addition, important new uses of the House were developed during the year, including meetings held during the January Independent Activities Period. At the same time, the House remains underutilized and will have to await an economic upturn to realize its full educational potential— or the addition of perhaps another major resident program comparable to the Senior Executives Program. The House was used only two-thirds of the time in 1971-72.

Demand for conference facilities continued to decline everywhere as academic budgets reflected stringent conditions throughout the country. As a conference center, Endicott House experienced slightly reduced demand. M.I.T. groups accounted for roughly 90 percent of the resident conference volume and roughly 75 percent of the non-resident conference volume. Miss Aimee Pierson notes that the House was open for the full 12 months of 1971-72 and used 243 (256) days, including 193 (180) nights by 22 (26) resident conferences. (The comparable statistics for the preceding year are in parentheses.) Overnights totaled 4,612 (3,951) representing an average of 23.5 (21.5) guests per night. In addition, 88 (97) non-resident groups, representing a total of 4,647 (6,258) guests used the House during the year. A total of 17,739 (18,354) meals were served during the year, an average of 73 (71.5) meals per day of operation. In summary, fewer but slightly larger and longer resident conferences compensated for fewer and smaller non-resident conferences--both at higher prices. Special thanks are due Miss Pierson, Manager, and the staff at Endicott House for their constant attention to service and beauty, which give the House its distinctive qualities. Miss Pierson has provided superb management for Endicott House.

During the year, Vice President Constantine B. Simonides, Professor Wilbur B. Davenport, and Corporation Member, Christina H. Jansen, were elected to the Board of Governors. The Vice President and Secretary wishes to thank Malcolm G. Kispert who completed many years of faithful service on the Board. The Board of Governors also acknowledges a continuing debt to the Staffs of Physical Plant and the Accounting Office for valuable assistance rendered to the Manager and to Endicott House.

To conclude this report on the 1971-72 year, other personnel changes included the joint appointment of Leslie M. Boring, Jr. by the Department of Chemical Engineering and the Vice President and Secretary to serve as project officer to plan and fund new facilities for the Department. In his new position as Special Assistant, Mr. Boring succeeds Kendall B. Randolph who resigned to accept a position in industry. At year's end, David J. Tobin was appointed Special Assistant in the Office of the Vice President and Secretary to devote a greater portion of his time to the strengthening of Visiting Committee administration. He was succeeded as Institute Secretary for Charitable Trusts by Arnold H. Singal.

The Vice President and Secretary of the Institute has now completed nine years and is entering the tenth year of his appointment. This has involved the high privilege of serving in this post under three distinguished M.I.T. Presidents—Drs. Stratton, Johnson, and Wiesner—and two magnificent Chairmen—Drs. Killian and Johnson. The Corporation has exercised great wisdom in making these choices as it has in the additional election of Dr. Gray as Chancellor and the appointment of Dr. Rosenblith as Provost.

Readers of this report will understand the Vice President and Secretary's personal satisfaction in taking a busman's holiday during a few weeks in the summer of 1971 to organize support for the endowment of the James R. Killian, Jr. Faculty Achievement Award. This year's first Killian Laureate is Professor Nevin S. Scrimshaw of the Department of Nutrition and Food Science.

VINCENT A. FULMER

# Other Offices

## Alumni Association

Alumni Fund

This past year the Alumni Association received $2,793,743 from 22,067 donors. These are both new records, exceeding the record of $2,680,077 established in 1969 and the 21,344 donor record of 1971. This was the ninth consecutive year that the number of donors exceeded the preceding one -- an achievement not equalled by any other major fund during this period.

The number of donors of $100 and up continued to grow at a faster rate than the total number of donors; the 25th (Class of 1947) and 50th (Class of 1922) Reunion Classes set new records, and the Class of 1917 broke new ground by announcing the Association's first 55th Reunion Gift. Alumni, through telethons, talked to over 9,000 other alumni, securing more than 5,000 pledges as this form of solicitation achieved a new high in volume and effectiveness. Many of the Association's regions were incorporated into these telethons, which accounts for the fewer number (163) of regions organized this year.

Area councils grew in effectiveness. These now function in 11 major alumni centers, involving leading alumni in active direction of the Fund in their areas. Through councils, agents, reunion committees, telethons, and regional and special gift solicitations, the Fund continues to involve more alumni than any other activity. This involvement, and the acceptance of responsibility it represents, are fundamental strengths of the Institute. To use it effectively is the Alumni Association's challenge.

*Technology Review*

The current year has been an outstandingly good one for Technology Review. Through a combination of planning and circumstance, the Review was able to publish a series of ten articles on energy supply, energy demand, and energy technology in the first three issues of Volume 74 which, taken together, represented an outstanding contribution to the growing national debate on these topics. The direct, pragmatic approach of the series contrasted with the more science oriented coverage of the same general theme in Scientific American's special issue of September, 1971, a contrast which the Association thinks may separate typically the Review's approach from that of some other journals with which it may appear to compete.

The ten articles subsequently were collected into a paperback book titled Energy Technology to the Year 2000, of which some 7,500 are now (June, 1972) in print and 6,300 sold. Most of the unsold balance will be used in subscription premium offers. Other significant editorial features of the year have included a series of articles on solid waste disposal; two articles on technological issues and options by J. Herbert Hollomon, Class of 1940, Director of the Center for Policy Alternatives; an article -- widely quoted -- on "The Case for Institutional Assessment" by Frank P. Davidson of the M.I.T. System Dynamics Group; and three articles on the technology and economics involved in development of short-haul air transport systems

based on VTOL and STOL aircraft.

The Association believes the Review is finding and developing its central editorial thrust, and it believes that its quality is now becoming widely recognized by alumni and others throughout and beyond the U.S. Indeed, the Association believes the Review now has influence far beyond its modest circulation figures, which at the close of 1971-72 totaled some 50,000 copies.

Of this total circulation, 35,500 represents copies to alumni (26,000 undergraduate and 9,500 graduate), and 14,500 are copies to non-alumni "paid" subscribers. This latter record in part can be attributed to a higher renewal rate for existing "paid" (non-alumni) subscribers than the publication has had before. The consequence is that the non-alumni "paid" subscribers are, in fact, beginning to make a positive financial contribution to Technology Review, as well as a significant audience for "M.I.T.'s story" as it is represented by the magazine.

The year was not without its difficulties. To meet the financial constraints of M.I.T.'s budgets, the Association was forced to make substantial economies just as it began to see an increase in the magazine's readership and apparent influence; it reduced the page size and otherwise modified the format of the Review, reduced the number of pages, and reduced the number of issues from nine to eight per year. In common with other magazines devoted to technology, the Review has experienced difficulty in attracting advertising. Despite aggressive efforts to place the Review before executives of corporations and advertising agencies as a growing medium for their messages, the magazine's advertising volume and revenues for 1971-72 will be essentially unchanged from 1970-71. Yet there are indications that advertising commitments by technology based companies will be higher in the coming year and that Technology Review may be added to a number of schedules.

## Alumni Relations Program

This year 11 alumni seminars were conducted in five different cities on six different topics, as follows: How To Start and Operate a Small Business; Entrepreneurship Workshops; Technology and the Economy of the Seventies; Providing Energy for the Future; Probability Block 1; and The Future Character of the Urban Fringe.

The book M.I.T. Entrepreneurship Register 1971 was published as a direct outgrowth of last year's successful program of seminars. Its purpose was to facilitate continuing contact among alumni and participants in the Entrepreneurship Workshops conducted in five different cities. In addition, the book Energy Technology to the Year 2000 published by Technology Review was a direct by-product of the Alumni Seminar held in Cambridge on that subject and repeated in Washington.

The manuscript is now complete for the Association's third book, How to Start a New Business, which will be published by The M.I.T. Press in the fall of 1972. This book, likewise, is a direct product of the alumni seminars conducted during the past three years.

The seminar, "Probability Block 1," conducted in New York was an experimental program in cooperation with the Center for Advanced Engineering Study wherein the Association sought to combine the unique educational resources of the Center with the marketing and organizing ability of the Alumni Association as one way of expanding the Institute's educational influence beyond Cambridge.

Although alumni seminar attendance was less than anticipated on the basis of prior years' experience, it is still the Association's intention to expand this program in the future. Major attention during 1972-73 will be devoted to preparing a four-year program for alumni seminar development, including market studies and the development of a formal plan for faculty support from the Institute.

The Alumni Association was pleased to be asked to participate in planning for the inaugural events for the first week in October, 1971. A total of 485 alumni and guests formed a significant part of the audience attending the formal investiture ceremonies on October 7, 1971, at which time President Jerome B. Wiesner was made an Honorary Member of the Alumni Association.

During their first year in office, President Wiesner and Chancellor Gray logged over 30 visits to M.I.T. alumni groups around North America. This, together with Alumni Day and reunion weekend, provided an opportunity for the President and the Chancellor to appear personally before 2,800 different alumni.

The Reunion and Alumni Day weekend in June was considered to be the finest conducted in recent years. Total attendance was 2,594 alumni, guests, and other members of the M.I.T. community. This included 1,297 at the 12 reunions (of which 7 were held on the M.I.T. campus) as well as 2,654 who attended the Homecoming activities, including 2,473 at "Tech Night at the Pops" at Symphony Hall.

During the year, 45 M.I.T. clubs in North America held 150 meetings which were attended by an estimated 5,400 alumni with a total attendance of 8,600. The Association arranged for 52 Institute speakers for these meetings as well as 7 speakers for 10 overseas club meetings.

New this year were the six area alumni officers meetings, wherein all alumni officers in a local area are invited to meet with a senior member of the Academic Council for the purpose of exchanging information about Institute and alumni affairs.

## Nominations and Elections

The Alumni Association nominated three alumni members to the Corporation and one additional Corporation member in the category of Representatives from Recent Classes. In addition, 58 alumni were nominated to fill alumni vacancies on the Corporation Visiting Committees.

The Association's Constitution and By-laws were amended to broaden and liberalize procedures for nomination and election of officers of the Association and alumni nominees to the M.I.T. Corporation. Some of these changes have been implemented already, including the inauguration of at least one annual face-to-face meeting of the National Nominating Committee and the expansion of information about candidates on the Alumni Association's annual ballot. The full impact of these broadened and liberalized procedures will begin to be felt in the fall of 1972 with consideration of more than one candidate per vacancy on the annual ballot and the opportunity for candidates to include personal statements. The Association believes these changes will significantly increase the participation of alumni in these important elections.

## Alumni Records

Last year the Alumni Association and the Office of Administrative Systems completed a long-range study and system design for a completely new data-processing system for the Alumni Association. During 1971-72, the detailed system design was completed and a new data bank was made available as of July 1, 1972.

As of April 1, 1972, the rolls of living alumni included 59,440 names, a net decrease of 582 this year, resulting from adding 1,835 alumni of the Class of 1971, removing the names of 548 alumni reported deceased, and removing 1,869 from the rolls in a continuing effort to refine the files. During the previous 12 months, 16,819 address changes were recorded. The number of alumni in the "address missing" category totaled 3,686 or 6.2 percent of the roster.

### Staff Changes

Jeffrey Ingram, Class of 1958, has resigned after three years as Associate Director of the Alumni Fund. During this time, he brought the Association's telethon programs to a high level of professionalism, established a coherent solicitation organization for the Graduate School, and made many other contributions.

O. Reid Ashe, Class of 1970, came to Technology Review in September, 1971, as Assistant Editor, resigned to take an editorial post with the Charlotte Observer (North Carolina) in order to broaden his experience. He has been an excellent reporter -- and especially an able science writer -- for the Review.

Even more serious for the Review is Fred Wheeler's resignation to return to Britain. In almost four years as Managing Editor, Mr. Wheeler has made uniquely important contributions. He is an able editor, a thoughtful writer, and a skillful student of new technological developments and their real significance.

Panos D. Spiliakos, Class of 1966, resigned from the position of Assistant Secretary of the Alumni Association. During his four years with the Association, he has improved significantly the system of staff support for alumni reunions and has contributed importantly to the current series of M.I.T. alumni seminar programs.

This report would be incomplete without a tribute to those who have made these accomplishments possible, namely, the thousands of alumni volunteers and their leadership -- and special tribute should be paid Paul V. Keyser, Class of 1929, 77th President of the Association, an extraordinary leader and the first in 65 years to serve two terms in this office.

DONALD P. SEVERANCE

## Institute Information Services

The years 1970-72 were marked both by a major retirement and by reorganization of those Institute offices working in the areas of information, both for the Institute community and for the general public.

Francis E. Wylie, M.I.T. Director of Public Relations for more than 15 years, retired in October, 1970. A veteran professional newsman, Mr. Wylie became during his career at M.I.T. one of the leading university news officers in the United States. He ably represented M.I.T. through periods of great growth and great achievement, as well as change. His advice and counsel were sought not only by those at M.I.T. who knew him as a colleague but by those at other institutions who knew of him by reputation and achievement.

In February, 1971, the Institute Information Services (I.I.S.) was formed to oversee and to provide general administrative support to its three principal subunits: 1) the News Office (formerly the Office of Public Relations); 2) the Publications Office; and 3) the Information Center (formerly a division of the Office of Campus Information Services which was dissolved upon reorganization). Robert M. Byers, formerly Associate Director of Public Relations, was named Acting Director of I.I.S. and Director of the News Office. Paul E. Johnson, who had been Director of Campus Information Services and who had left the Institute for a brief period, returned as Associate Director of I.I.S. William T. Struble continued as Director of the Publications Office, and Mary L. Morrissey continued as administrative assistant for the Information Center.

### News Office

The newly formed News Office experienced vigorous activity during its inaugural two years. As part of its responsibility to provide the thousands of people who live and work at M. I. T. with the big and little news that makes up daily life at the Institute, the News Office undertook conversion of Tech Talk, formerly an employees' newsletter, into a community-wide weekly tabloid newspaper of general appeal and interest. Joanne Miller, who had been editor of the newsletter, continued as the editor of the newspaper which was received with wide encouragement. Because the newspaper is a central forum for announcements, news, and reports and because of its method of printing and distribution, the Institute has been able to provide timely news to the M. I. T. community at significantly lower costs.

As part of its responsibility to provide news about the Institute to the general news media -- newspapers, magazines, television, and radio -- the News Office issued over 500 separate news releases. These included numerous releases, plus publicity support, for the highly successful 1970 Clean Air Car Race organized by M. I. T. and California Institute of Technology students. Other major news events which drew News Office support were the elections of new officers of the Institute and the role of the Draper Laboratory in the Apollo 14 mission to the moon, as well as substantive research results from most of the Institute's academic departments and interdepartmental laboratories.

During this period, Peter M. Spackman, formerly Editor of Cultural Affairs, Quarterly Journal of the Arts (published by Associated Councils of the Arts), joined the staff as editor of Reports on Research. William Stuckey resigned his position.

### Office of Publications

The Office of Publications completed 231 publishing projects in 1970-71 and 233 in 1971-72. Total publications expeditures declined by more than 20 percent during the period. Dietmar R. Winkler, a graphic designer who had been with the office since 1966, resigned to accept the position of Design Director of WGBH-TV. As in the past, M. I. T. 's graphic design work was displayed widely in separate exhibitions, including that of The American Institute of Graphic Arts, and in prominent international periodicals. Jacqueline S. Casey and Ralph Coburn were guest lecturers at the Massachusetts College of Art, and Mrs. Casey served as a guest lecturer at the Yale University School of Design.

### Information Center

While the Information Center has continued to carry on its traditional responsibilities for students, prospective students, parents, visitors, and the M. I. T. community at large, it also has undertaken new directions. The Center became a liaison office for internal communication to the Institute by being the central distribution point for the printed M. I. T. reports, publications, and notices.

A major breakthrough for the Center was the physical redesign of the office which was completed in the fall of 1972. Following this project, the Center undertook evening, weekend, and holiday service, absorbing the information functions previously handled by Physical Plant during those hours.

ROBERT M. BYERS

## The M.I.T. Press

During fiscal year 1971-72, university presses sought to stabilize their financial positions. They did so in response to the effects on their operations of the state of the economy as a whole, specific funding difficulties in their parent institutions, reductions in research grants and of specific publishing subsidies associated with such grants, declines in library funding, declines in the size of bookstore inventories, and a detectable reluctance of scholars them-

selves to purchase as many new books.

In fiscal year 1970-71, the M. I. T. Press itself, which receives no operating subsidy, had operated at a deficit of about $150,000 (which did not result in the use by the Press of any general Institute funds, but was financed entirely by the retained earnings accumulated by the Press during previous years). It is pleasing to report that, without severe staff reductions and without a sharp effect on the nature of the publishing program of the Press, in fiscal year 1971-72, the year here reviewed, the operating deficit of the Press was reduced to about $32,000 (an amount again entirely recovered from retained earnings), and the sales income of the Press was the highest recorded in its history, $2,637,000 -- a rise of over 8 percent compared to the previous year.

## The Publishing Program

During fiscal year 1971-72, the Press published 119 and produced, either directly or as imports, 112 new books, bringing the number of titles published since 1963, when the Press became an independent publishing organization and its previous association with John Wiley & Sons was terminated, to a total of 977. The level of operation during the year of report, predicted in the last Annual Report of the Press as "a deliberate turning back calculated to increase the profitability of the publishing operation," constitutes an annual rate of book output that is 18 percent lower than the maximum annual rate during prior years. Please see Table I for a cumulative analysis of output and net sales.

Categorized broadly, the new books published during the year fell into the following classes (figures from earlier years are shown for reference):

| Year | Social Science | Humanities | Engineering | Science and Mathematics | Art and Architecture |
|---|---|---|---|---|---|
| 1969-70 | 28% | 15% | 24% | 16.5% | 16.5% |
| 1970-71 | 26 | 12 | 23 | 26 | 13 |
| 1971-72 | 22 | 11 | 27 | 27 | 13 |

The substantial weight of publications in the pure and applied sciences is, the Press believes, an emblem of the fulfillment of what is understood as the prime function of the Press. However, the Press itself will be required to accommodate its editorial policies to shifts of emphasis within the disciplines themselves, in the same way that in the Institute as a whole the design of curriculum and the allocation of resources responds to such changes.

As a group, for example, books in engineering science have been among those showing a downward trend in sales. To maintain strength in this area, it is necessary to reduce the cost of publication, to find title subsidy, or, more directly, to refuse, on financial grounds, to publish.

Overall, the constant aim of the Press remains to publish those works founded in research and learning that exhibit the high standards of significance within their subjects and excellence of execution that are characteristic of the teaching and research activities of the Institute as a whole. Some such books will find wide sales and receive wide public acclaim; some will be regarded just as highly but by an intrinsically much smaller audience. The Press must exist within a real financial context, and some narrow books must be turned down at this point, because they are narrow.

Important points of policy are being raised here, and they deserve restatement. The Press

TABLE I
Publications and Sales

| | 1962-63 | 1963-64 | 1964-65 | 1965-66 | 1966-67 | 1967-68 | 1968-69 | 1969-70 | 1970-71 | 1971-72 |
|---|---|---|---|---|---|---|---|---|---|---|
| New Hard-cover Books | 18 | 43 | 49 | 57 | 65 | 54 | 83 | 86 | 84 | 82 |
| Paperbacks | 0 | 10 | 17 | 20 | 20 | 20 | 32 | 42 | 25 | 28 |
| Imports | 0 | 5 | 12 | 9 | 15 | 2 | 10 | 17 | 11 | 9 |
| Total New Books | 18 | 58 | 78 | 86 | 100 | 76 | 125 | 145 | 120 | 119 |
| Book Sales (Net) | $301,000 | 487,000 | 1,027,000 | 1,210,000 | 633,000 | 1,608,000 | 1,905,000 | 2,573,000 | 2,434,000 | 2,637,000 |

has no intention of allowing itself to become a disguised commercial publisher. On the other hand, the reality is that during the last calendar year those university presses reporting operating subsidies, in cash or in kind, received on the average an amount equal to 17.5 percent of their net sales in this way. The M.I.T. Press continues to receive only a few percentage points of such support and none of it in such a form as to reduce measurably direct operating expenses. Two of the principal competitors among the university presses receive annual operating subsidies that are reported to amount to several hundreds of thousands of dollars. For the M.I.T. Press the necessity is considerably greater to find and publish some books that have the potential of selling very well indeed and to maintain the facilities to market them aggressively so that such books will, in fact, achieve the sales potential the Press recognizes in them.

Commitment to an educational role leads the Press to approach text publishing more formally than it has in the past. A limited program of text acquisitions exists in the sciences on the high undergraduate and graduate levels. Conventional text publishing, particularly at the lower educational levels and outside the sciences, has shown a serious softness in recent years. Xerox has indeed made every man his own publisher, and changes in student attitudes and educational philosophies have played a role, too. However, the Press tends to believe that these characteristics will not be felt as much in most of the sciences and at the levels the Press intends to address.

Finally, a special responsibility to the humane studies is felt. The Press believes that a publishing program of discrete size in that area can do much to convey the intellectual richness and breadth of concern characteristic of the Institute. Important resources in the visual arts are already available that, for example, can support important contributions in art and photography. In this connection, the Press is seeking to build a relationship with the M.I.T. Council for the Arts.

## New Book Acquisition

During fiscal year 1971-72, the Acquisitions Department of the Press (five members, no change) reviewed 1,350 new manuscripts and proposals, a number that is 18 percent lower than the comparable figure for the previous year. Of the total number of projects offered to the Press for publication, over 70 percent were declined by the editorial staff of the Press, another 23 percent were declined by the staff in consultation with exterior scholarly readers, and the remainder not accepted for publication were still under consideration at the conclusion of the period this report covers.

Fewer than one percent of the projects presented to the Editorial Board for its approval were declined by the Board, though the consideration of some was deferred for fuller documentation or investigation of specific queries raised by Board members. The ten members of the Board appear to be acting with something close to absolute approbation of the editorial policies exercised by the Press acquisitions staff. Often Board scrutiny does elicit publishing counsel from Board members, ranging from suggestions about titles to proposals for editorial revision. If the imprint of the Press is to remain under the effective control of the Institute faculty, attention should be devoted to relating the Board more meaningfully to the editorial concerns of the Press.

It is a nice balance that is sought. Outside their own areas of specialty, the specific editorial expertise of the members of the Board is only by accident likely to be equal to that of the editors themselves. In judging financial aspects of projects presented to them, Board members also will be relatively uninformed. Yet the perspective of the Board may be better than that of the members of the Press staff who are involved directly in appraising new projects, their sense of the broad interests of the Institute may be better, and most of all their independence of particular party or point of view is likely to be more secure.

In the summer months most faculty members are peripatetics, and to preserve continuity of action by the Board in that period is an ancient difficulty that never has been solved adequately. During the forthcoming year it may be advisable to experiment with the creation of Board subcommittees, each consisting of a Board member and perhaps two other professors of his choice, focusing on a subject area of significance in the Press publishing program and appropriate to the strengths of the Board member concerned. Such subcommittees might be empowered to act for the full Board during the summer recess, with the understanding that their decisions would be subject to review by the whole Board at the succeeding formal meeting.

During the year of report, the Board met six times, under the interim chairmanship of Professor Robert A. Bishop and, beginning November 1, 1972, when he completed other pressing commitments, under the chairmanship of its new head, Dean Robert A. Alberty. Members of the 1971-72 Editorial Board were: Professor Sylvain Bromberger (Department of Humanities); Professor Bernard Burke (Department of Physics); Professor Charles P. Kindleberger (Department of Economics); Professor Norman Levinson (Department of Mathematics); Professor Salvador E. Luria (Department of Biology); Professor Kevin A. Lynch (Department of Urban Studies and Planning); Professor J. P. Ruina (Department of Electrical Engineering); Professor Edgar H. Schein (Sloan School of Management); and Professor Gardner C. Swain (Department of Chemistry). At the conclusion of the year, Professors Bromberger, Levinson, and Luria completed their terms of service.

## Text Editing

Under the able leadership of a new Managing Editor, this department (11.5 members, plus 0.5, as compared to the previous year) functioned with calm competence and commitment, processing in some stage during the year 178 projects and in the course of doing so editing to a refined level of textual integrity that characterizes M. I. T. Press books over 30,000 manuscript pages.

## Media

The Media Department (10 members, no changes), reorganized to embrace both design and production functions under the leadership of the former Design Director, who is now known as Media Director, continued to maintain the high design standards that distinguish the Press while it developed the pattern of unified graphic services that is found in most other book publishing environments.

Heavy emphasis was given during the year to the development of an in-house composition facility as a means of making some inroad upon the sharply rising costs of composition, of accelerating the pace of manufacture, and of laying the foundation for a more ambitious information system that will permit the Press to provide important new services to the community of scholarship.

The development program follows earlier Press experiments with the IBM "Datatext" system, using time shared facilities offered by a commercial service firm. The basic installation at this time is the PDS 1D IMLAC mini-computer with CRT display and associated console, financed by an anonymous gift to the Press. With special programming produced in association with Professor Nicholas Negroponte and his research group and the technical support of students working under the U. R. O. P. program, the IMLAC now is permitting encoding of complex text, including mathematical signs and symbols, with basic formatting codes, for correcting, reading out on tape, translation for a commercially available CRT composition device, and generation of reproduction proof in the facsimile of type ready for conventional photo-offset printing. This system now is being employed in a small number of selected book projects as part of the operating production process.

## Marketing

The Marketing Department (Marketing: 10.5 members, minus 1; Order Fulfillment: 6.7,

no change) is charged both with the responsibility for selling, advertising, and promoting M.I.T. Press books and other products and for operating the order fulfillment mechanism of the Press. Warehousing and clerical EDP services are provided, as in the past, by contract with Device Development/Technical Impex, Inc., of Lawrence, Massachusetts (an arrangement that has been under continuing review for some years, in the expectation that the Press ultimately may wish to consider performing these functions for itself, perhaps in conjunction with another university publishing house).

The general return on marketing investment may be compared as follows:

| | $ 1967-68 | $ 1968-69 | $ 1969-70 | $ 1970-71 | $ 1971-72 |
|---|---|---|---|---|---|
| Total marketing expense | 330,000 | 346,000 | 492,000 | 511,000 | 493,345 |
| Net Sales | 1,609,000 | 1,905,000 | 2,572,000 | 2,435,000 | 2,637,000 |
| Volume of sales per dollar invested | 4.88 | 5.51 | 5.23 | 4.77 | 5.35 |

The percentage of marketing expense to net sales has varied during the same span of time from 20.5 in fiscal year 1967-68 to 18.7 in the year of report. The recorded average for 41 presses in calendar 1971 was 19.0, for 11 large presses, 17.5. In estimating these figures it is necessary to reference percentage of marketing expense for scientific and technical publishers for the calendar period cited above: 19.1.

The marketing function can be analyzed into selling, direct mail, space advertising, exhibit, and promotion activities. During the year of report three domestic salesmen called on 1,230 accounts, many four or six times. The direct mail effort reached 1,380,000 readers announcing or reannouncing almost 700 books. In particular, a very successful direct mail book sale, imaginatively conceived and executed, generated about $350,000 of income, while also reducing inventory write-down.

All new titles appeared in list ads in at least four media and at least once in descriptive advertisements. A total of 107 advertisements were run, and approximately 40,000 copies of seasonal catalogues were distributed by mail and directly, at exhibits or by some other means. During the year of report, M.I.T. Press books were exhibited at 48 scholarly or trade meetings. A total of 15,000 review copies of 134 titles were dispatched, using a new computer based system of media selection, and among the resulting notices were three major reviews in the New York Times Book Review Section.

Of all sales during the year, 47 percent were backlist and 53 percent new list (less than 18 months since publication). In fiscal year 1967-68, the comparable figures were 58 percent and 42 percent.

For the year of report, returns were 14.0 of net sales, as against 16.2 percent the previous year.

The London sales office of the Press, operating cooperatively with the University of Chicago

Press, generated $365,815 in sales, a slight rise over the previous year but one essentially resulting from a favorable fluctuation in the currency exchange rates rather than any increase in business.

## Financial Department

Under a new financial manager, this department (11 members, plus 1), consisting of an accounting section, including the accounts receivable function, and a credit and collections section, made progress in increasing the quality of the Press operation in this area. More is needed. In particular, the development of credit policy, particularly with regard to the approximately 5,000 individual or uncoded accounts now maintained, is a matter of some priority.

During the year, the Press was able (with some difficulty) to computerize the royalty calculations. The current cost-center budgeting is an advance over the earlier system. Success was realized in restricting the need for new operating capital to its lowest point in some years, and the inventory write-down was 5.6 percent of net sales (as against an industry percentage in calendar 1971 of 7.0 percent).

The gross margin percentage for the year of report was 54.4 (since fiscal year 1967-68, the comparable figures are 57.0, 58.3, 53.9, and 53.9).

Accounts receivable are a fraction lower than the previous year, although sales increased by $200,000. The aging of the receivables, however, is not up to industry standards, and that is a function of the effects of the unusual number of unscreened individual accounts referred to above, historically generous credit policies (for so-called agency accounts, for example, and some prime coded accounts), and conventional difficulties in crediting returns against original orders. It is, however, worth observing that, although 50.3 percent of the accounts are 60 days and over in age (as against reported figures for calendar 1971 of 35.7 for all university presses), the bad debt cost expressed as a percentage of net sales was 0.7 (for calendar 1971, the average percentage among university presses was 0.6).

During the year of report the Press accepted, as an extraordinary write-off, a charge of $81,430 (not included as an ordinary operating cost), principally owing to the correction of a computer anomaly in the registration of off-site inventory, which for a period of three years preceding had overstated inventory value.

The balance of retained earnings after the completion of the year of report was $205,504. The maximum accumulation of retained earnings was $484,803, in June, 1970.

## Journals Department

This new department (3 members, plus 2) has brought together functions that were, to the detriment of the services provided to the five journals published earlier, distributed throughout a number of existing departments. One journal was discontinued as a result of this reorganization, and the remaining publications are: The Journal Interdisciplinary History, Linguistic Inquiry, Newsletter for the Science and Public Policy Studies Group, and Studies in Applied Mathematics.

Under new leadership and with clearly defined functions, the department has raised sharply the quality of service and is engaged actively in developing a number of additional journal publications.

## Administration

The Director's Office (4 members, minus 1) devoted most of its resources to the administration of the Press, though some are applied in such other areas as Institute relations, industry and professional activities, and planning, research, and learning in advanced communications.

The 61.7 employees of the Press generated $42,735 net sales each (as against a reported university press average for calendar 1971 of $24,758). This productivity is gratifying in one sense; in another, it is a sign of overtaxed staff resources. The Press suspects that it maintains the lowest number of employees per $100,000 sales among the university publishing houses. If it maintained a staff of average size, its employee strength would be 95.

A policy question is raised by these figures, and it will be among the questions brought to the attention of the Management Board, a new governing body scheduled to meet for the first time in fall, 1972. The Management Board (similar in function to the Board of Directors maintained by some other presses) is established, in the words of Jerome B. Wiesner, President of the Institute, "to provide support and guidance to the management of the Press on a wide range of issues, including reviews of the budget and reviews of operating and long-range policies of the Press as a publishing organization within M.I.T." There are three ex officio members: the chairman, Constantine B. Simonides, Vice President of the Institute; Robert A. Alberty, Dean of the School of Science and current chairman of the Editorial Board; and the Director of the Press. Other Institute members are Paul V. Cusick, Vice President, Business and Fiscal Relations, and Michael S. Scott-Morton, Professor of Management. In addition, two distinguished publishers from outside the Institute are members: George M. Fenollosa, senior vice-president, Houghton Mifflin Company; and Jack Schulman, manager, Cambridge University Press.

The general administrative challenge continues to be to define the publishing role of the Press in an environment that does not provide subsidy or comparable exterior funding, in which the posture of the Press has been historically ambitious, in which the rate of income increase has been reduced substantially, in which a relatively stable level of output has been reached, in which interest, inventory revaluation, and occupancy expense have risen sharply, in which new technological opportunities have been presented, in which some of the narrow monographic publication accommodated in the past years is no longer financially possible, and in which strongly motivated staff members desire a publishing context that is strongly rewarding.

HOWARD R. WEBBER